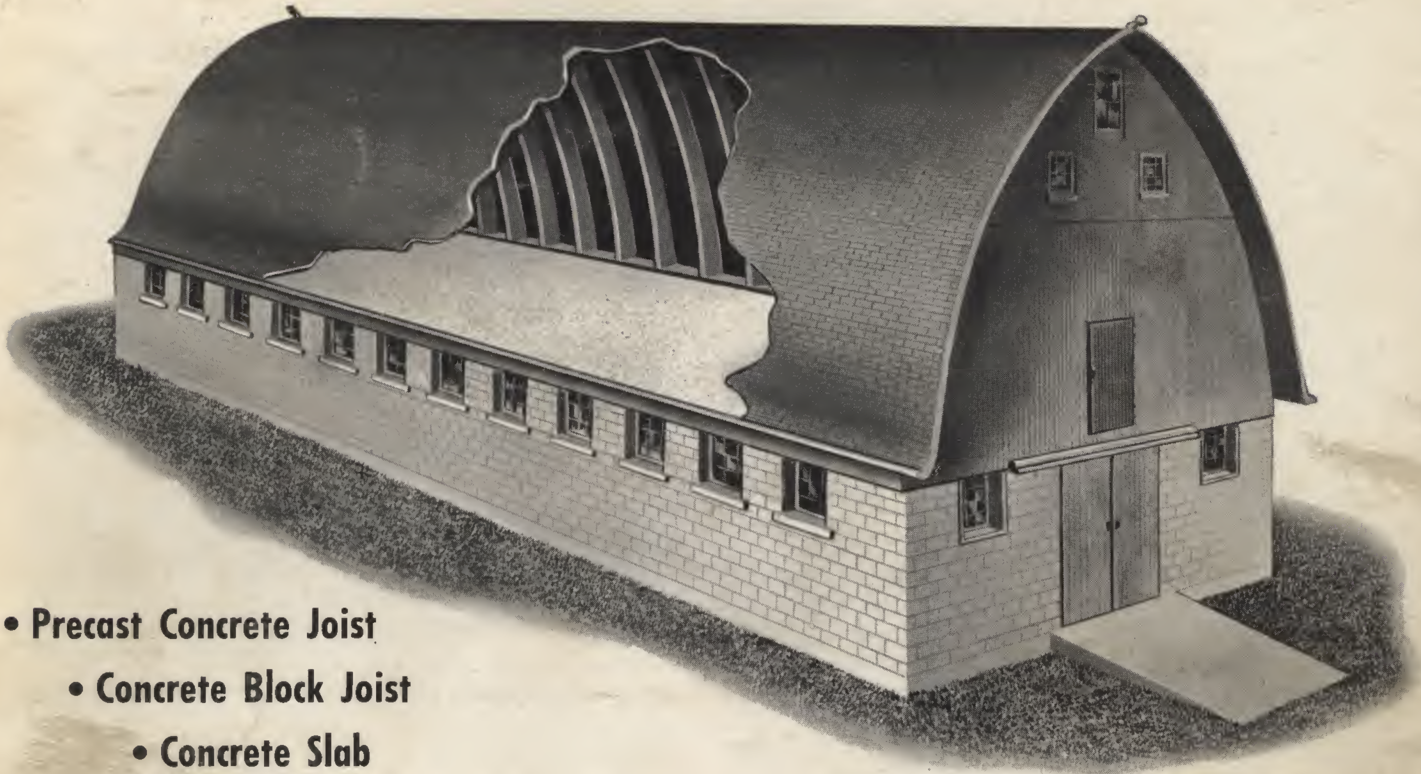
Bob. McCabe
Huron Cement Co.

A DESIGN MANUAL FOR

Concrete Farm Floors



- **Precast Concrete Joist**
- **Concrete Block Joist**
- **Concrete Slab**

SUPPORTED concrete floors have particular value for many different kinds of farm buildings. In two-story barns a concrete hayloft floor reduces the ever-present fire danger involved in storing highly combustible hay above the livestock. Smooth concrete floors in multistory poultry houses make cleaning and disinfecting rapid and easy. Concrete subfloors in farm homes are fire resistant, rigid, and free from warping or squeaking.

Fire hazard in barns where hay or feed is stored overhead is especially great. Unless the barn has a fire-resistant hayloft floor, a hay fire, once it starts, seldom can be put out or brought under control. The building and all its contents will usually be a total loss. While the building, crops and livestock may be fully insured, money cannot pay for the loss in years of selective livestock breeding or for the disruption of farm activities caused by fire.

A concrete hayloft floor confines hay fires and gives the farmer time to lead his livestock to safety with little danger involved. The first story of a barn with a concrete hayloft floor is usually undamaged by fire. Livestock are not deprived of shelter for more than a few hours and the barn can be restored by the addition of a new roof.

Many top-quality farm products can be produced only in buildings that are kept sanitary and healthful. For example, the modern dairy barn must be kept clean to safeguard milk. Poultry houses require thorough cleaning and disinfecting from time to time, especially when diseases threaten the flock. Concrete floors and ceilings are easily washed and cleaned. They have no crevices to harbor filth and disease, and dust or chaff cannot sift through them.

The many benefits of a concrete floor are available at little or no extra cost over combustible construction. Economy of forming is possible as standard span lengths of farm floors allow many reuses of forms.

The farmer must have planning aid before proceeding with construction—from the state college, the local concrete products plant, a barn equipment manufacturer, farm builder, or a practicing agricultural engineer.

This booklet, which outlines simple design and construction techniques, is published as an aid to those who are asked to help the farmer plan a reinforced concrete floor.

The drawings in this publication are typical designs and should not be used as working drawings. They are intended to be helpful in the preparation of complete plans which should be adapted to local conditions and should conform with legal requirements. Working drawings should be prepared and approved by a qualified engineer or architect.

PORTLAND CEMENT ASSOCIATION 33 W. GRAND AVE., CHICAGO 10, ILL.

HOW TO DESIGN A REINFORCED CONCRETE FLOOR

To design a concrete floor to fit the needs of the individual farmer:

1. Decide on building width and span lengths.
2. Determine the loads to be carried.
3. Select the floor to carry the design loads.

Each of these three simple steps in design is discussed in detail in the following paragraphs. The steps are followed in the three illustrative problems accompanying the design tables.

STEP 1. Determine Building Width and Span Lengths

Width of farm buildings varies according to use and individual preference, but in most cases intermediate girders are required for support of the overhead floors. Three-span construction with two supporting girders parallel to the building length is most common. Buildings 30 to 40 ft. wide are usually built in this manner. Greater width can be achieved by adding additional spans. The main rule to follow in spacing girders is to place them so that the supporting columns interfere least with efficient operations in the building.

The width of many farm buildings is determined by the floor space required to carry on the operations within the building. For example, most stanchion dairy barns are built 36 ft. wide. This width permits an efficient arrangement with two rows of cow stalls and three service alleys running the long direction of the barn. See Fig. 1. If larger stalls are used a barn width of 38 or 40 ft. may be required; if a mechanical gutter cleaner is installed a narrower litter alley is possible and a 32- or 34-ft. barn will often be wide enough.

Fig. 2 shows a cross-section of a 36-ft. wide barn. Here, the supporting columns are located in an out of-the-way place near the back of the stall platform. This location makes the lengths of the end or side spans 11 ft. and the interior or center span 12 ft.

STEP 2. Determine Loads

Farm floors used for other than storage purposes, such as floors in multistory poultry houses or farm homes, are designed for some recommended uniformly distributed load. Table 1 shows the usual design loads for several different types of farm buildings. These should be modified if greater loads than indicated are expected.

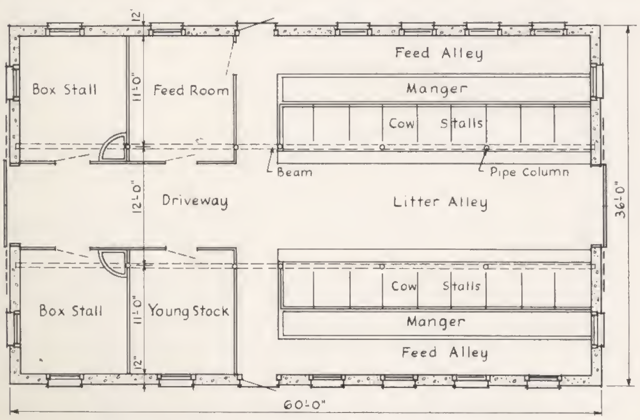
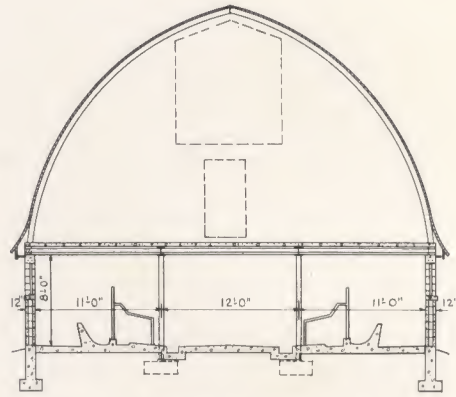


Fig. 1. Floor plan of 36-ft. wide dairy barn.



. Fig. 2. Cross-section of 36-ft. wide dairy barn.

Floors that carry loaded trucks or wagons must be designed for concentrated wheel loads. Table 2 gives equivalent uniform loads which may be used in designing such floors. These loads cause stresses in the floor equivalent to those produced by the wheel loads of a truck having a total weight of 5 tons.

The expected loads on floors which carry feed or bedding, such as floors in a hayloft, may be estimated by multiplying the unit weight of the material stored by the expected depth of the pile. Table 3 gives unit weights of some of the farm products commonly stored overhead.

Hayloft floor loads also can be estimated by dividing hay and bedding needs of livestock by the floor space required to house the livestock. Table 4 gives hayloft floor loads for stanchion dairy barns. These loads are based on the hay and bedding requirements given in Table 5 and on a cow stall width of 3 ft. 6 in. A sample derivation of loads on an end and an interior span is given in the footnote to Table 4. The uniform load is increased by 25 per cent to cover year-to-year variations in production and uneven distribution of hay. The resulting

TABLE 1—Floor and Roof Loads on Farm Buildings

Load description	Usual design load (psf)*
Floor	
Farm home	40
Poultry house	35
Light machinery storage	100
Stables	75
Roof	
Flat	30
Over 1/6 pitch	20

*Pounds per square foot.

TABLE 2—Uniform Loads Equivalent to Wheel Loads of 5-Ton Truck*

Span length (ft.)	Equivalent uniform loads		Distribution steel**
	End spans (psf)	Interior spans (psf)	Per cent of main reinforcement
14	137	142	27
13	147	153	28
12	159	166	29
11	173	181	30
10	191	199	32

*Truck plus load = 5 tons.

**To distribute concentrated wheel loads laterally, this quantity of steel must be used at right angles to the main reinforcement.

TABLE 3—Average Weights of Material Stored on Farm Floors*

Type of feed	Weight (pcf)**
Hay—loose	4
chopped	10
baled	14
Straw—baled	12
Shavings—baled	20
Grain—shelled corn, wheat,	48
oats, ear corn	26
Concentrates	20 to 40
Fertilizer in bags	45 to 60

*These weights may vary depending on compaction and moisture content of material.

**Pounds per cubic foot.

TABLE 5—Hay and Bedding Required for One Cow (1000 lb. wt.) in Stanchion Barn*

	Hay (lb.)	Bedding (lb.)	Total (lb.)
Zone 1 (210 days feeding)			
If hay is only roughage fed	5250	1260	6510
If both hay & silage are fed	3150	1260	4410
Zone 2 (175 days feeding)			
If hay is only roughage fed	4375	1050	5425
If both hay & silage are fed	2625	1050	3675
Zone 3 (140 days feeding)			
If hay is only roughage fed	3500	840	4340
If both hay & silage are fed	2100	840	2940

*From _Northwestern Regional Bulletin No. 7_ (Bul. 470, University of Wisconsin) 1949.

uniform load is increased by 20 per cent for interior spans and decreased by 10 per cent for end spans since this is the usual storage pattern. Only the area above the stanchion portion of the barn was used in the derivation.

Hay loads on the floor of a drive-in type hayloft are heavier than in the more conventional type. In order to keep the driveway portion clear, more of the hay and bedding is piled in the end sections of the barn. Design loads in Table 4 should be increased for drive-in type haylofts by the ratio of floor area in the driveway section to floor area not in the driveway section.

It is recognized that not all farmers can regulate their crop production within the limit used in Table 4. In good crop years, farmers often store more hay than they expect to feed the next season. If this is the practice or intent, then the engineer has no alternative than to design for heavier loads. It should be remembered, however, that heavier design loads usually increase costs. It is seldom economical to design for hay loads in excess of 200 psf.

STEP 3. Select the Floor to Carry Design Loads

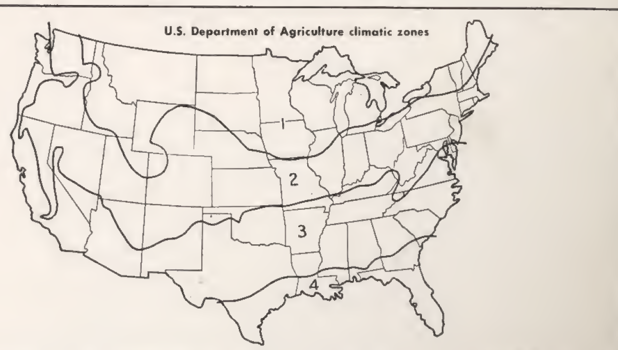
Load tables are included to aid the designer in selecting members of adequate strength. The tables are based on the American Concrete Institute Code (318-51), "Building Code Requirements for Reinforced Concrete," except that the coefficient for positive moment in end spans of continuous members is assumed to be 1/11 instead of 1/14. Assumed concrete and steel stresses are shown in the tables. Use of high bond reinforcing bars complying with ASTM specification A-305 is assumed. These bars are officially designated by number but throughout this booklet numbers and diameters are used interchangeably as follows:

No. 2 — ¼-in. round bar	No. 6 — ¾-in. round bar
No. 3 — ⅜-in. round bar	No. 7 — ⅞-in. round bar
No. 4 — ½-in. round bar	No. 8 — 1-in. round bar
No. 5 — ⅝-in. round bar	

Engineers thoroughly familiar with reinforced concrete design sometimes prefer to determine moment and shear coefficients for the individual job. Such designs will usually be slightly more economical than the more general solution shown in the tables.

TABLE 4—Hayloft Floor Loads Determined from Hay and Bedding Needs

	Load on end span (psf)	Load on interior span (psf)
Zone 1		
If hay is only roughage fed	124*	165*
If both hay & silage fed	84	111
Zone 2		
If hay is only roughage fed	103	136
If both hay & silage fed	70	92
Zone 3		
If hay is only roughage fed	82	110
If both hay & silage fed	56	75



*Derivation: Total hay and bedding needed = 6510 lb. (Table 5)

Floor space for one cow $= \frac{\text{net barn width}}{2} \times \text{stall width} = \frac{34}{2} \times 3.5 = 59.5$ sq.ft.

Uniform load $= \frac{6510}{59.5} = 109.5$

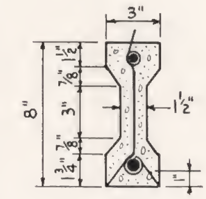
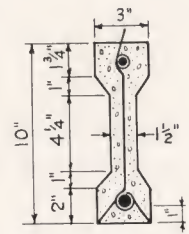
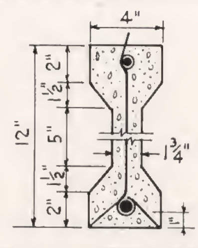
Add 25 per cent for yearly carryover $1.25 \times 109.5 = 137$

Load on end span $= 137 \times 0.9 = 124$

Load on interior span $= 137 \times 1.2 = 165$

Precast concrete joist floors are clean and fire-resistant. Methods of construction are similar to those used in building wood floors.

PRECAST CONCRETE JOIST

Col. 1	Col. 2		Col. 3	Col. 4
Joist cross-section	Size of reinforcement		Joist spacing (in.)	Slab thickness (in.)
	Top bar	Bottom bar		
	#3	#5	33 30 27 24 20	2½ 2½ 2 2 2
	#3	#6	33 30 27 24 20	2½ 2½ 2 2 2
	#3	#7	33 30 27 24 20	2½ 2½ 2 2 2
	#3	#6	33 30 27 24 20	2½ 2½ 2 2 2
	#3	#7	33 30 27 24 20	2½ 2½ 2 2 2
	#3	#8	33 30 27 24 20	2½ 2½ 2 2 2
	#3	#6	33 30 27 24 20	2½ 2½ 2 2 2
	#3	#7	33 30 27 24 20	2½ 2½ 2 2 2

Bar nomenclature: #3 = ⅜"φ, #5 = ⅝"φ, #6 = ¾"φ, #7 = ⅞"φ, #8 = 1"φ

Precast concrete joist floors have many characteristics that are ideal for farm construction. The reinforcing steel is built into the joist as it is cast at the products plant. Thus, when the joist is set most of the reinforcing is in place and need not be a concern of the builder.

The techniques of construction with a concrete joist floor are familiar, as they are quite similar to the methods of framing wood floors. Concrete joists are set in much the same manner as wood joists. A cast-in-place concrete slab over the joist takes the place of the wood flooring. Forming for the cast-in-place slab is simple. No shoring is required; the forms are supported by the joists themselves.

The completed concrete joist floor is one of the lightest types. It is usually not used when subjected to concentrated loads such as heavily loaded trucks or wagons.

Precast concrete joists are made in three common sizes, 8, 10 and 12 in. deep. Typical cross-sections of these three sizes of joists are shown in Design Table A. Each of the joists can be obtained with various sizes of reinforcing bars in the bottom flange and with different stirrup arrangements. These are important factors affecting their load-carrying ability. The loads in Design Table A are based on the assumption of simple beam moments, thus the table is usable for any number of spans. Most manufacturers do not stock standard lengths but make up joists on individual orders.

Typical construction procedures with precast joists are illustrated on pages 6 to 9. Many builders have developed variations to some of the steps in construction. The illustrations should not be interpreted as showing the only methods of obtaining satisfactory results; rather they show some of the methods which have been successfully used.

Illustrative Design

PROBLEM: To design a concrete hayloft floor for a dairy farmer in Wisconsin. He has no silo and needs enough hayloft capacity to store hay and bedding for a herd housed in a conventional dairy barn.

STEP 1. Determine Spans. The hayloft floor will be supported by the side walls and by two girders paralleling the barn length. In order to keep supporting columns out of the driveway and gutter space, floor spans of 11-12-11 ft. are used. (Clear spans will be less than these measurements by the length of bearing of the joists on the girders. However, since this dimension is small and neglecting it is on the side of safety, the clear end spans will be considered as 11 ft. and the clear interior span as 12 ft.)

STEP 2. Determine Loads. Wisconsin will be found to be in Climatic Zone No. 1 on the map accompanying Table 4, page 3. Consulting the part of the table which applies to Zone 1 when hay is the only roughage fed, design loads of 124 psf on each end span and 165 psf on the interior span are selected. These loads can be converted into approximate heights of stored materials by dividing them by the unit weights given in Table 3. For example, loads on the end spans would be equivalent to loose hay 31 ft. deep or baled hay about 9 ft. deep. Loads on the interior span would be equivalent to chopped hay 16½ ft. deep or baled hay 11½ ft. deep.

STEP 3. Determine Joist Sizes and Spacings. The joists for the interior span will be selected first, since this is the longer span and carries the heavier load. The span length is 12 ft.; the expected loading is 165 lb. Enter Design Table A at Column 6 and find a span of 12 ft. Move vertically down this column until a load of 165 lb. or more is found. The first figure satisfying this requirement is 165 lb. Projecting horizontally from 165 to other columns in the table yields the following information:

FLOORS

DESIGN TABLE A—Safe Superimposed Loads on Precast Concrete Joist Floors

Col. 5	*Col. 6*							*Col. 7*
Dead load of floor (psf)	**Safe superimposed load (psf) on floor with clear span of: (ft.)**							**Stirrup arrangement** — **No. 6 wire stirrups spaced as shown at each end of joist. Balance of stirrups 18-in. centers.**
	8	**9**	**10**	**11**	**12**	**13**	**14**	
36	144	103	74	52	36	23		5 4 4 4
37	162	117	85	61	43	29		
32	181	134	101	76	57	42	31	
32	*	156	118	90	69	53	40	
34	*	191	146	113	88	69	53	
36	199	164	123	93	70	53	38	5 4 4 4 4 4
37	*	183	139	106	81	61	46	
32	*	*	156	122	96	75	59	
32	*	*	181	142	113	90	72	
34	*	*	*	175	140	113	91	
36	195	168	146	128	111	87	68	5 4 2 4 4 4 4 4 4 4
37	*	188	164	144	125	99	78	
32	*	*	182	162	143	115	93	
32	*	*	*	187	165	134	110	
34	*	*	*	*	*	166	137	
38	*	*	166	128	100	78	60	5 4 5 4 5 4
39	*	*	185	144	113	89	70	
34	*	*	*	164	131	105	85	
35	*	*	*	188	151	122	99	
37	*	*	*	*	186	152	124	
38	*	*	195	172	151	121	98	5 4 2 4 5 4 5 4 5 4
39	*	*	*	193	170	137	111	
34	*	*	*	*	190	156	129	
35	*	*	*	*	*	179	148	
37	*	*	*	*	*	*	183	
38	*	*	191	169	151	135	122	5 4 2 4 5 4 5 4 5 4
39	*	*	*	189	169	152	138	
34	*	*	*	*	190	172	157	
35	*	*	*	*	*	197	180	
37	*	*	*	*	*	*	*	
42	*	*	*	160	126	99	79	5 4 6 4
43	*	*	*	180	142	113	90	
39	*	*	*	*	162	131	106	
41	*	*	*	*	185	150	123	
44	*	*	*	*	*	185	152	
42	*	*	*	*	188	152	124	5 4 6 4 6 4
43	*	*	*	*	*	171	140	
39	*	*	*	*	*	192	159	
41	*	*	*	*	*	*	182	
44	*	*	*	*	*	*	*	

Maximum loads as limited by code or practice:
*200 psf

Codes:
ACI 318-51
ACI 711-46

Allowable stresses:
Steel f_s = 20,000
Concrete joist f'_c = 3,750
Concrete slab f'_c = 3,000

Column 1—An 8-in. deep joist
Column 2—A No. 3 ($\frac{3}{8}$-in. ϕ) top bar
A No. 7 ($\frac{7}{8}$-in. ϕ) bottom bar
Column 3—Joist spacing 24 in.
Column 4—Slab thickness 2 in.
Column 5—Floor dead load 32 psf
Column 7—Five stirrups at each end of joist arranged as shown

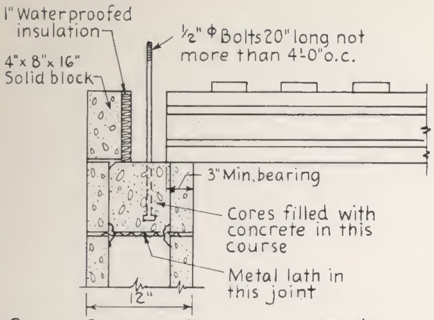
By proceeding on down the column headed *12 ft.*, other joists and other spacings can also be found which would carry loads of 165 lb. or more. However, in order to space joists farther apart than 24 in., a 10- or 12-in. deep joist would be required.

The depth of joists for both interior and end spans should be the same in order to have a level hayloft floor. Since the interior span is longer than the end spans and carries a heavier load, joist depth suitable for the interior span will be satisfactory for the end spans.

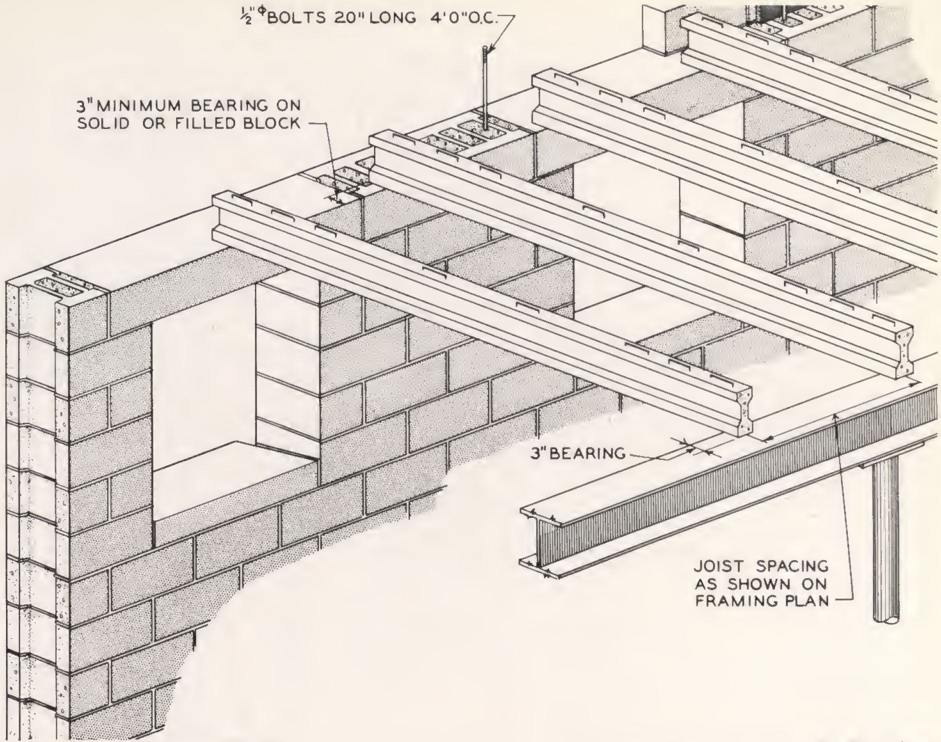
Joist spacing and reinforcing for the end spans are determined in the same manner as for the interior span. Enter Design Table A at Column 6 with a span of 11 ft. and move vertically down this column until a load of 124 psf or more is found. There are several combinations of joists and spacings that will be satisfactory for this loading. A 27-in. spacing is convenient for forming and bridging of joists. The first load greater than 124 for an 8-in. joist at 27-in. spacing is 162. Projecting horizontally from 162 to other columns gives this information

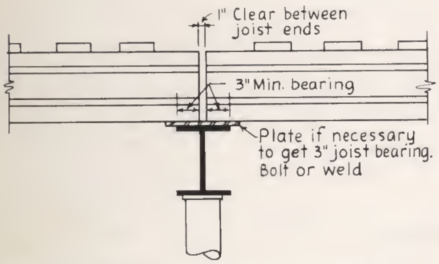
Column 1—An 8-in. deep joist
Column 2—A No. 3 ($\frac{3}{8}$-in. ϕ) top bar
A No. 7 ($\frac{7}{8}$-in. ϕ) bottom bar
Column 3—Joist spacing 27 in.
Column 4—Slab thickness 2 in.
Column 5—Floor dead load 32 psf
Column 7—Five stirrups at each end of joist arranged as shown

Some builders like to space the joists for the end spans at 24-in. centers since this is the usual rafter spacing. Rafters can therefore be bolted directly to the joists in the same manner as with wood joists. Holes for the bolts can be cast in the joists at the plant.

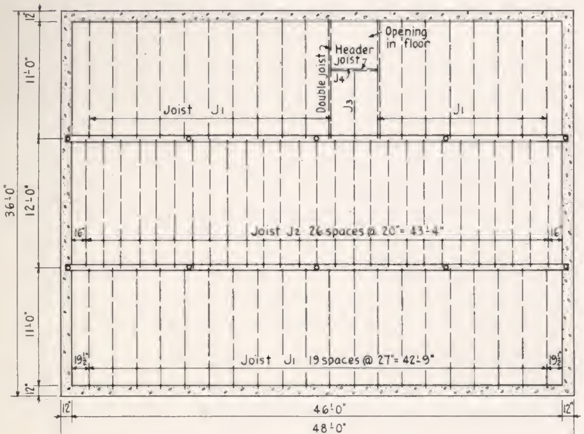


Cross Section Through Side Wall

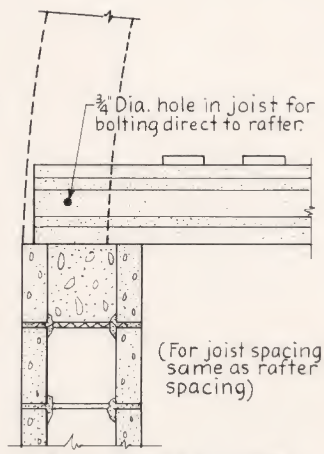




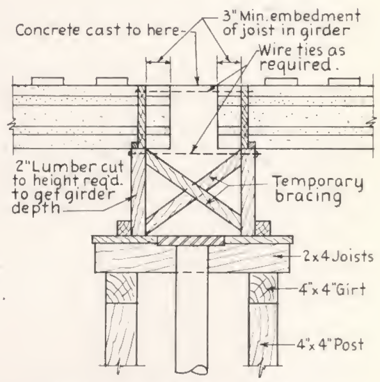
Cross Section Through Girder



Typical Joist Setting Plan

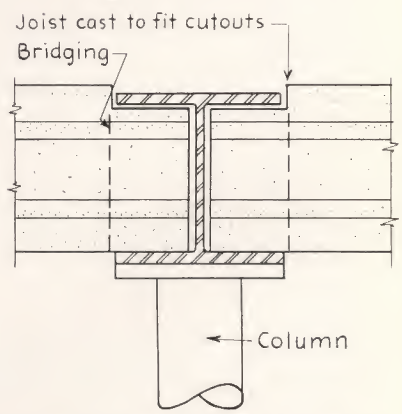


Full Bearing of Joist on Wall



Cast-In-Place Girder

Alternate Methods



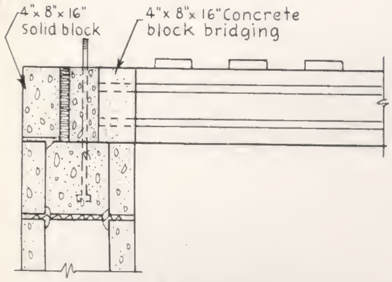
Joist Cast To Fit Into Steel Girder

Setting Joists

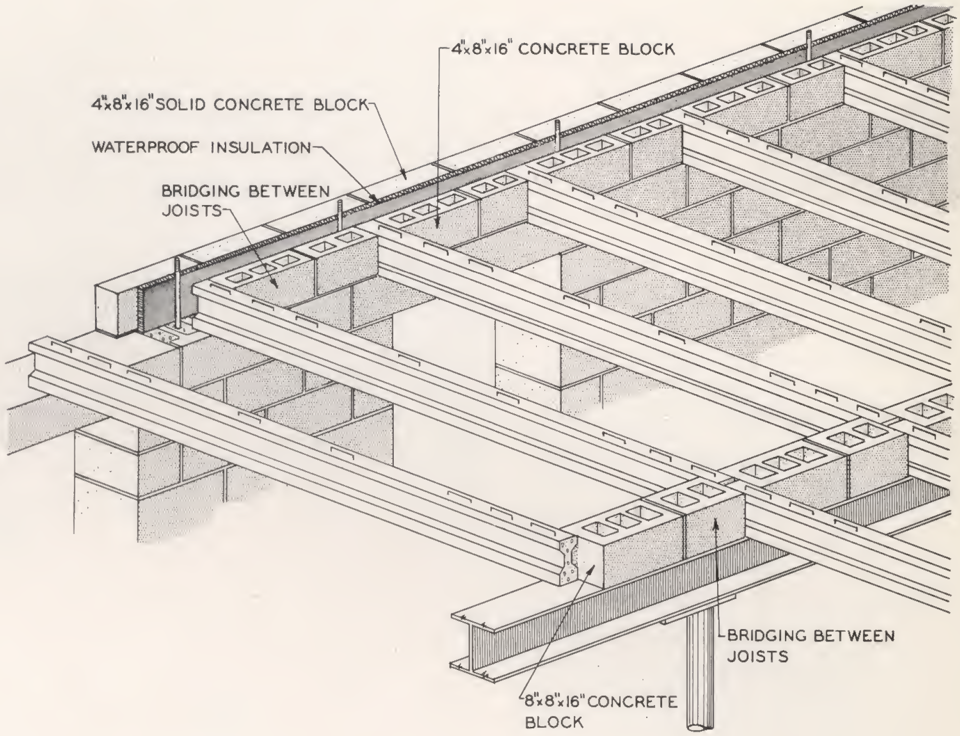
The concrete block walls are completed to the height at which the floor will be placed. The cores of the bearing course of block on which the joists will set are filled with concrete. A course of 4x8x16-in. solid concrete facer block is laid around the edge of the building and a strip of 1-in. waterproofed insulation is set on edge inside the facer units.

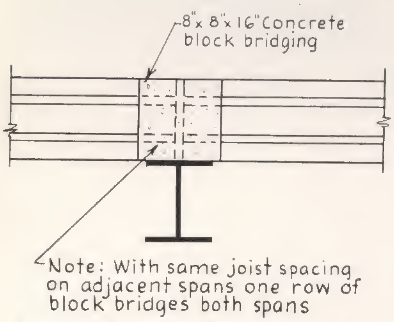
Girders are set with top surface level with the bearing course of the side wall.

Precast concrete joists having depth, length and reinforcement as required are then set according to the setting plan. Joists of the length required for farm floors can be handled by hand with no mechanical equipment. At least 3 in. of bearing should be allowed under each end of the joist.



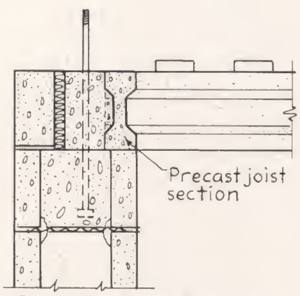
CROSS SECTION THROUGH SIDE WALL



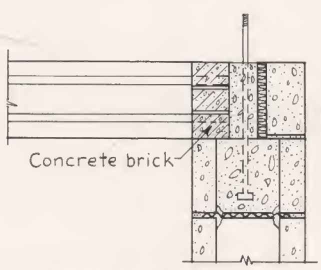


CROSS SECTION THROUGH GIRDER

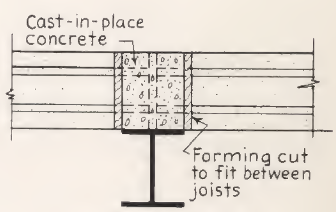
Alternate Methods



PRECAST JOIST BRIDGING



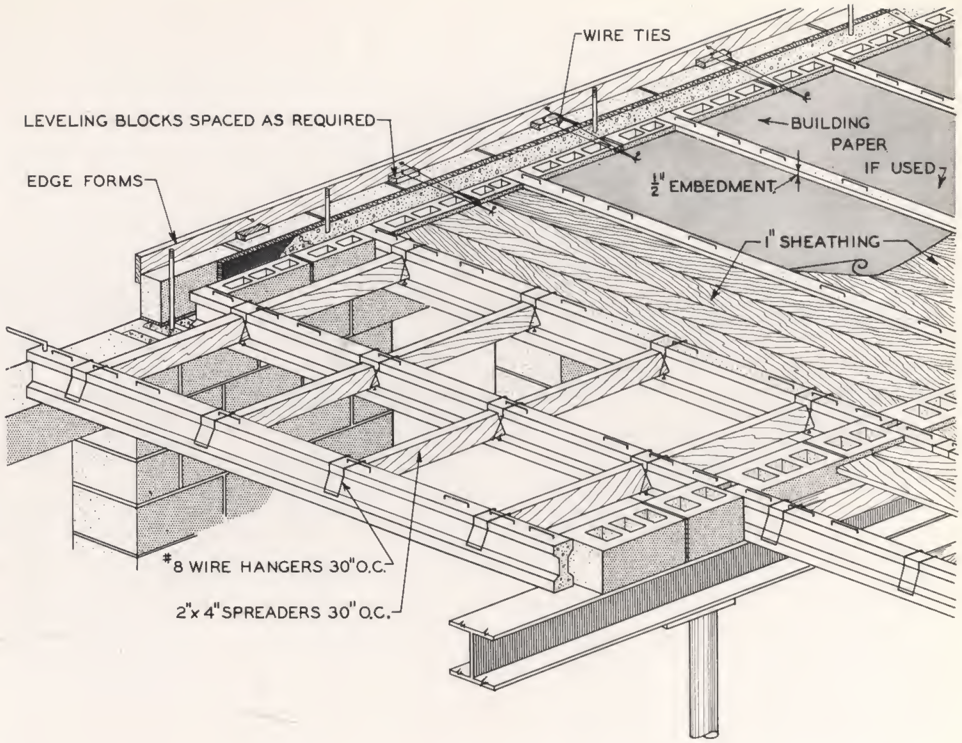
CONCRETE BRICK BRIDGING

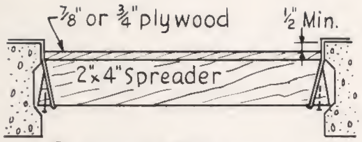


CAST-IN-PLACE CONCRETE BRIDGING

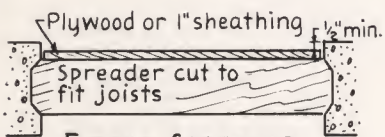
Bridging Joists

When the joists have been set at the required spacings they are bridged at each end. Bridging may be done with concrete block, short sections of joist, cast-in-place concrete or concrete brick. A 27-in. joist spacing is convenient if concrete block bridging is used, because the clear distance between joists is 24 in. A whole (16-in.) and a half (8-in.) block mortared in place will lay 24 in. No cutting of block is then necessary. If cast-in-place bridging is used, the space between joists is formed at each end and concrete is cast around the joist ends.

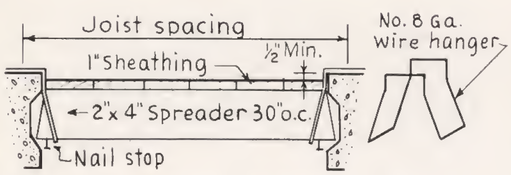




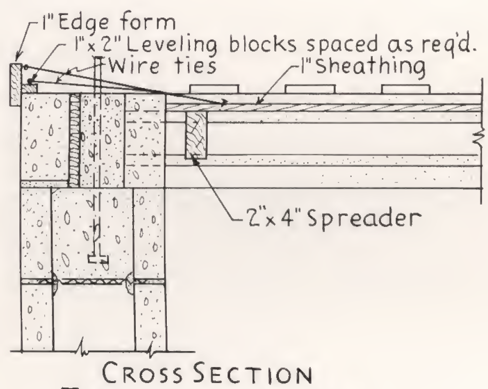
PLYWOOD FORMING



FITTED SPREADER



CROSS SECTION THROUGH JOISTS

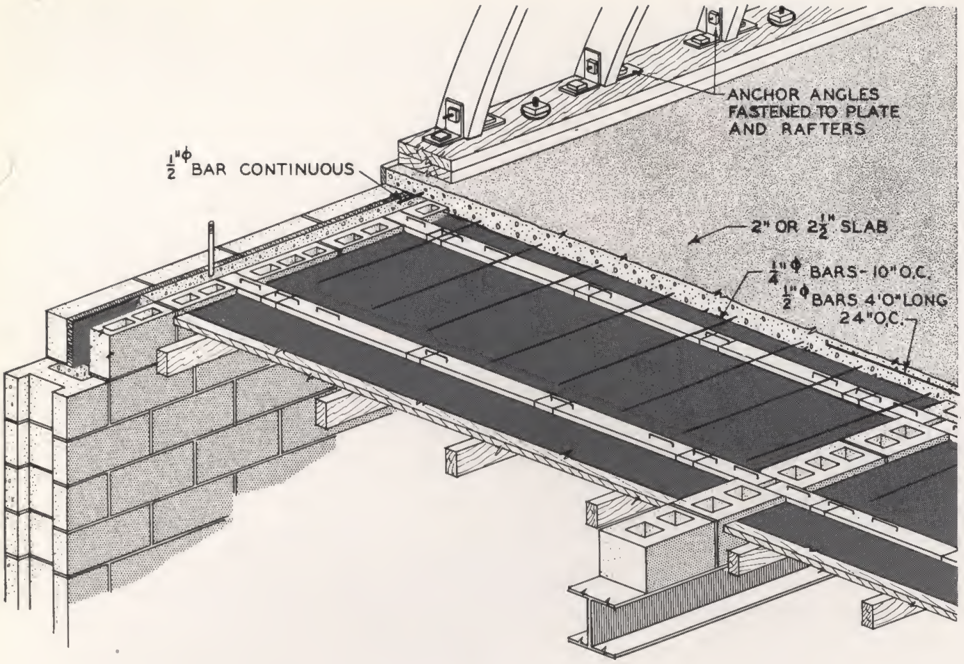


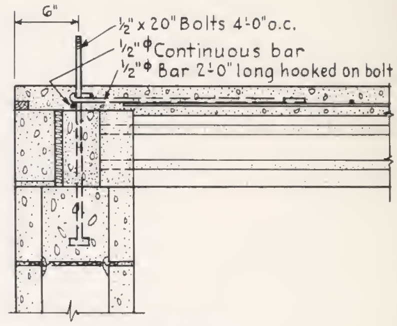
CROSS SECTION THROUGH SIDE WALL

Forming

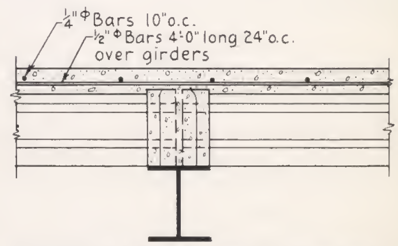
The formwork for farm floors is usually supported by the joists themselves. Short pieces of lumber called spreaders are placed crosswise between the joists at about 30-in. centers. These spreaders are held in place by wire hangars across the joist, by fitting them into the joist web, or by other means of support. Sheathing is then placed on the spreaders and tacked in position.

A 27-in. joist spacing is convenient if plywood sheathing is used, since a 2-ft. wide piece will just fit between joists. The surface of the sheathing should be ½ to ¾ in. lower than the top face of the joists; this allows the slab to bond securely to the joists. Building paper may be used over the sheathing if desired. However, most paper wrinkles and bonds to the concrete to some extent. If paper is not used the forms should be oiled to permit easy stripping. Neither paper nor oil should cover the top face of the concrete joists since it would interfere with proper bond when the concrete slab is placed over them.

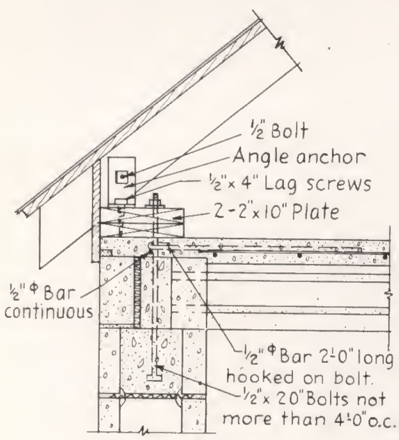




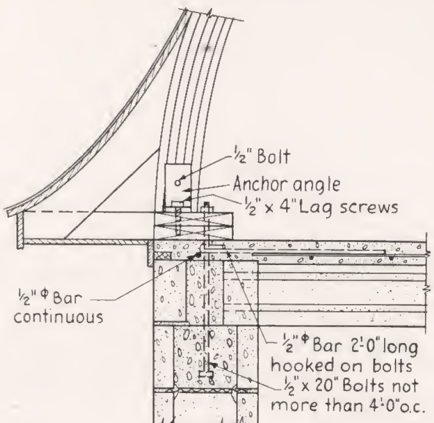
Cross Section Through Side Wall



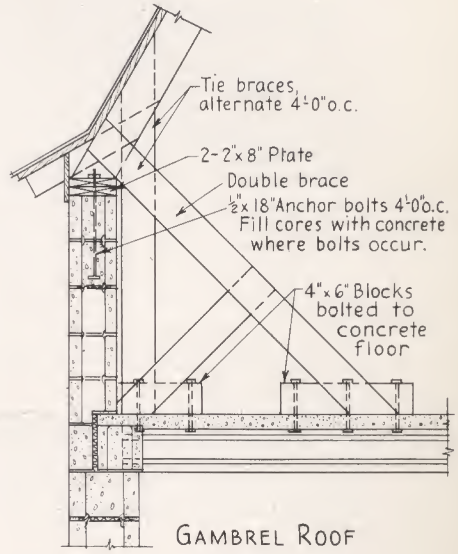
Cross Section Through Girder



Gable Roof



Gothic Roof



Gambrel Roof

Placing Steel, Concrete and Rafter Anchorages

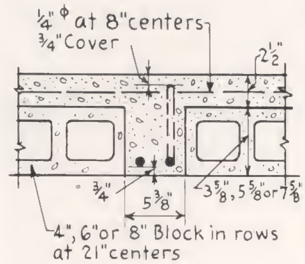
Reinforcing steel, ¼-in. round bars at 10-in. centers, is needed in the slab perpendicular to the joists. Bars parallel to the joists need to be put in only at sufficient intervals to hold the ¼-in. round bars at the proper spacing. Welded wire fabric, 6x6-in. No. 6 gage, may be substituted for the bars if desired.

Pieces of ½-in. round bars 4 ft. long should be placed in the slab over the girder at 24-in. centers. These rods should be parallel to the joists. Other ½-in. round bars 2 ft. long should be hooked around the anchor bolts to take the thrust the rafters exert on the floor. Bolts to hold the wood plate should not be set further apart than 4 ft. (See *Rafter Anchorage* detail).

Concrete having a mushy consistency should be placed and screeded to the desired level. The concrete slab may be placed on one span at a time, if desired, so that formwork can be reused. For instructions on making quality concrete see page 23.

A concrete block joist floor has excellent fire-resistant and insulative properties. The flat ceiling diffuses light evenly.

CONCRETE BLOCK JOIST



Col. 1	Col. 2	Col. 3	Col. 4
Floor cross-section	Nominal block thickness (in.)	Topping thickness (in.)	Dead lo[…] of floo[…] (psf)
	4	2½	5
	6	2½	6
	8	2½	8
	4	2½	5
	6	2½	6
	8	2½	8

Bar nomenclatur[e]
#3 = ⅜"φ
#4 = ½"φ

A concrete block joist floor gets its name from the fact that it combines concrete block with cast-in-place concrete joists and topping. The concrete block are placed in rows with spaces between the rows as shown in the illustrations on the following pages. Reinforcing rods are then placed in these spaces and the concrete for joists and topping is placed. This fresh concrete bonds with the block and holds them in position.

This type of floor is especially suited for farm construction because of its excellent fire resistance. Related to fire resistance are the insulative properties of the floor, which are also good. This means that less heat can pass through the floor and consequently moisture condensation problems are lessened.

The underside of the finished floor provides a flat ceiling in the building. Flat ceilings are easily washed, cleaned or painted and will diffuse light evenly to all parts of the structure.

Construction techniques are relatively simple and no special equipment is required. The builder who has had only limited experience in erecting formwork should have no difficulty after studying the sketches of typical forming details on the following pages.

Several patented types of forms are in common use. These can often be rented at a nominal cost—sometimes at less than the cost of constructing formwork. Shoring is used with some; others are supported on the walls and girders and need no shoring.

The most common thicknesses of concrete block joist floors are those obtained by using 4-, 6- or 8-in. block as filler. The corresponding total floor thicknesses (block plus topping) are 6⅛, 8⅛ and 10⅛ in.

Design Table B shows a typical cross-section of a block joist floor and gives safe loadings on floors having these three thicknesses. Various sizes of reinforcing rods are shown. The table is divided into loads on interior spans and loads on end or side spans.

This table may be used for any number of spans greater than one. For two-span construction both spans would be end spans. For three or more spans, all except the two end spans would be interior spans. A limitation on the tabulated loads is that the spans must be approximately equal. The longest should not exceed the shortest by more than 20 per cent.

Illustrative Design

PROBLEM: To design a concrete floor for a two-story poultry house. The building will be 40 ft. wide and a feed storage room will be provided on the second floor.

STEP 1. Determine Spans. If an 8-in. block wall is used, the clear inside width of the building is 38 ft. 8 in. End spans of 12 ft. 10 in. and an interior span of 13 ft. 0 in. will be used. This meets the requirement of Design Table B, that the longest span shall not exceed the shortest by more than 20 per cent. (Clear spans will be less than these measurements by the length of bearing of the floor on the girder. Since this dimension is small and neglecting it is on the side of safety, all spans will be considered as 13 ft. in this case.)

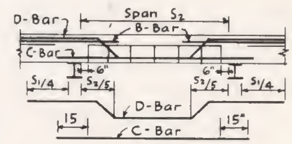
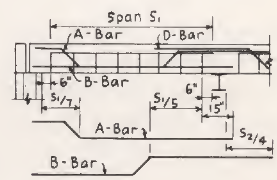
STEP 2. Determine Loads. The usual design load for poultry house floors as given in Table 1 is 35 psf. If heavy feed carriers or other equipment is suspended from the ceiling, the loads should be increased. In this case a feed carrier will be assumed to be attached at the center of the interior span. An allowance of 40 psf will be made for the feed carrier. Thus the end spans will be designed for 35 psf. The interior span will be designed for 75 psf.

The area for feed storage will be designed for 200 psf which is equivalent to a 5- to 10-ft. depth of concentrates depending on material.

STEP 3. Determine Block Size and Amount of Reinforcement Needed. The interior span will be designed first since it is more heavily loaded than the end spans. The span length is 13 ft.; the load, 75 psf. Enter Design Table B at Column 6 and locate

FLOORS

DESIGN TABLE B—Safe Superimposed Loads on Concrete Block Joist Floors

Col. 5				Col. 6							Col. 7
Reinforcing bar size				Safe superimposed load (psf) on clear span of: (ft.)							Shapes of bars
A	B	C	D	8	9	10	11	12	13	14	
INTERIOR SPANS $(+M = \frac{1}{16}wS_2^2;\ -M = \frac{1}{11}wS_2^2)$											
		#3	#3	112	77	52	34				
		#3	#4	*	*	131	99	74	55	40	
		#3	#5	*	*	*	*	138	109	87	
		#3	#4	**	**	**	155	119	92	71	
		#3	#5	**	**	**	**	**	171	139	
		#3	#5	***	***	***	***	***	***	186	
END SPANS $(+M = \frac{1}{11}wS_1^2;\ -M = \frac{1}{9}wS_1^2)$											
#3	#3			82	53	33					
#3	#4			*	133	97	71	51	35		
#3	#5			*	*	148	113	86	65	49	
#4	#5			*	*	*	133	103	80	61	
#3	#4			**	**	151	113	85	63	45	
#3	#5			**	**	**	172	135	105	82	
#4	#5			**	**	**	**	162	128	102	
#4	#6			**	**	**	**	**	187	153	
#3	#5			***	***	***	***	178	140	110	
#4	#6			***	***	***	***	***	***	***	

$\#5 = \frac{5}{8}''\phi$
$\#6 = \frac{3}{4}''\phi$

Max. loads as limited by code or practice:
*165 psf
**195 psf
***200 psf

Allowable stresses:
Steel f_s = 20,000
Concrete f'_c = 2,500
Blocks f'_c = 2,500 (on net area)

Assumed block weights:
4" = 15 lb. each
6" = 18 lb. each
8" = 23 lb. each

Code:
ACI 318-51

the 13-ft. span. Move vertically down this column into the portion of the table headed *Interior Spans*. The first loading which equals or exceeds 75 is 109. Reading across from 109 to other columns gives the following information:

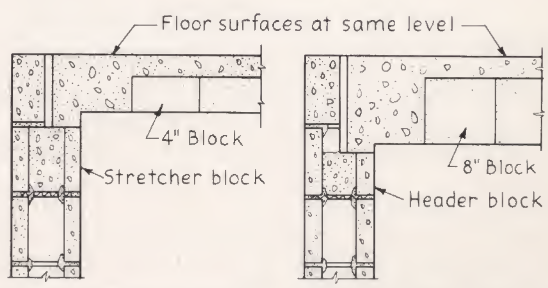
Column 2—A 4-in. nominal block thickness
Column 3—A 2½-in. topping thickness
Column 4—Floor dead load 55 psf
Column 5—*C* bar No. 3 (⅜-in. ∅)
D bar No. 5 (⅝-in. ∅)
Column 7—*C* and *D* bars bent as shown

The end spans are designed similarly. Enter Column 6 with a span length of 13 ft. Proceed down this column into the section of the table headed *End Spans*. The first tabulated load on a 13-ft. end span which is 35 or over is 35. Reading horizontally from 35 yields the following information:

Column 2—A 4-in. nominal block thickness
Column 3—A 2½-in. topping thickness
Column 4—Floor dead load 55 psf
Column 5—*A* bar No. 3 (⅜-in. ∅)
B bar No. 4 (½-in. ∅)
Column 7—*A* and *B* bars bent as shown

An identical procedure of design is followed for the section where feed is to be stored. For a 200-lb. design load and a 13-ft. span, an 8-in. block with 2½-in. topping is required. In interior spans a No. 3 (⅜-in. ∅) *C* bar and a No. 5 (⅝-in. ∅) *D* bar are needed. For the end span a No. 4 (½-in. ∅) *A* bar and a No. 6 (¾-in. ∅) *B* bar are needed.

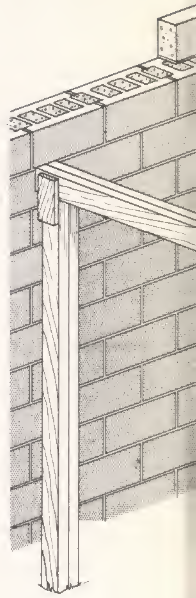
In order to keep the top surface of the floor in the feed storage area at the same level as the floor in the rest of the poultry house, header block may be used for the bearing course in the wall of the feed room. The detail shown is a typical section through the side bearing wall of the feed area and a comparable section through the wall of the housing area.



CROSS SECTION THROUGH BEARING WALL OF HOUSING AREA

CROSS SECTION THROUGH BEARING WALL IN FEED STORAGE AREA

Forming



The concrete block walls are first completed to the height at which the floor will be placed. A course of 4x8x16-in. solid concrete block is laid around the perimeter of the building to serve as the edge forms. Special care should be exercised when laying this top course to make it even and uniformly level all the way around since it will later be used as a guide for striking off the concrete.

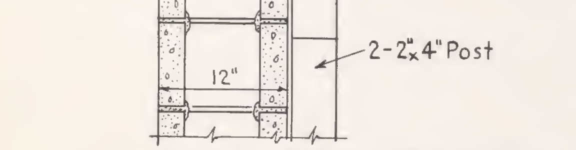
Girders should be set before form construction begins.

The steps in building open-type forming are shown on these pages. A solid type decking may be used in building block joist floors if desired. The first step in building open-type formwork is to erect posts (two 2x4-in.) and ledgers (two 2x6-in.). Ledgers are cleated to the posts with small pieces of 1-in. lumber. Spacing of ledgers may vary from 4 to 6 ft.; post spacing beneath ledgers should not exceed 6 ft. Posts should be securely braced in both directions.

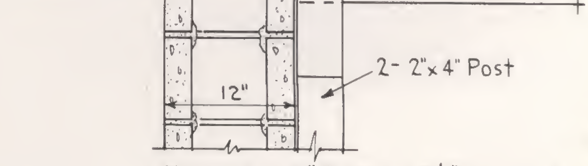
Wood joists (2x6-in.) are set on top of the ledgers and perpendicular to them. Maximum joist spacing is 30 in. Three joists at close spacing are required adjacent to the girders and walls. The final step in forming is placing of the soffit forms (2x8-in.). These are laid flatwise on top of the joists and parallel to the ledgers. Two pieces of 2x6-in. lumber are laid next to the girders and walls to form a solid decking at these locations.

This same type of formwork may be used for any thickness of floor. For the floor which is built with modular 4-in. block (3⅝-in. actually) the top surface of the soffit forms is set 1⅞ in. above the bearing course of masonry. This makes the finished floor flush with the top of the facer units. When 6- or 8-in. block are used, the top surface of the soffit forms is level with the bearing surface. See details.

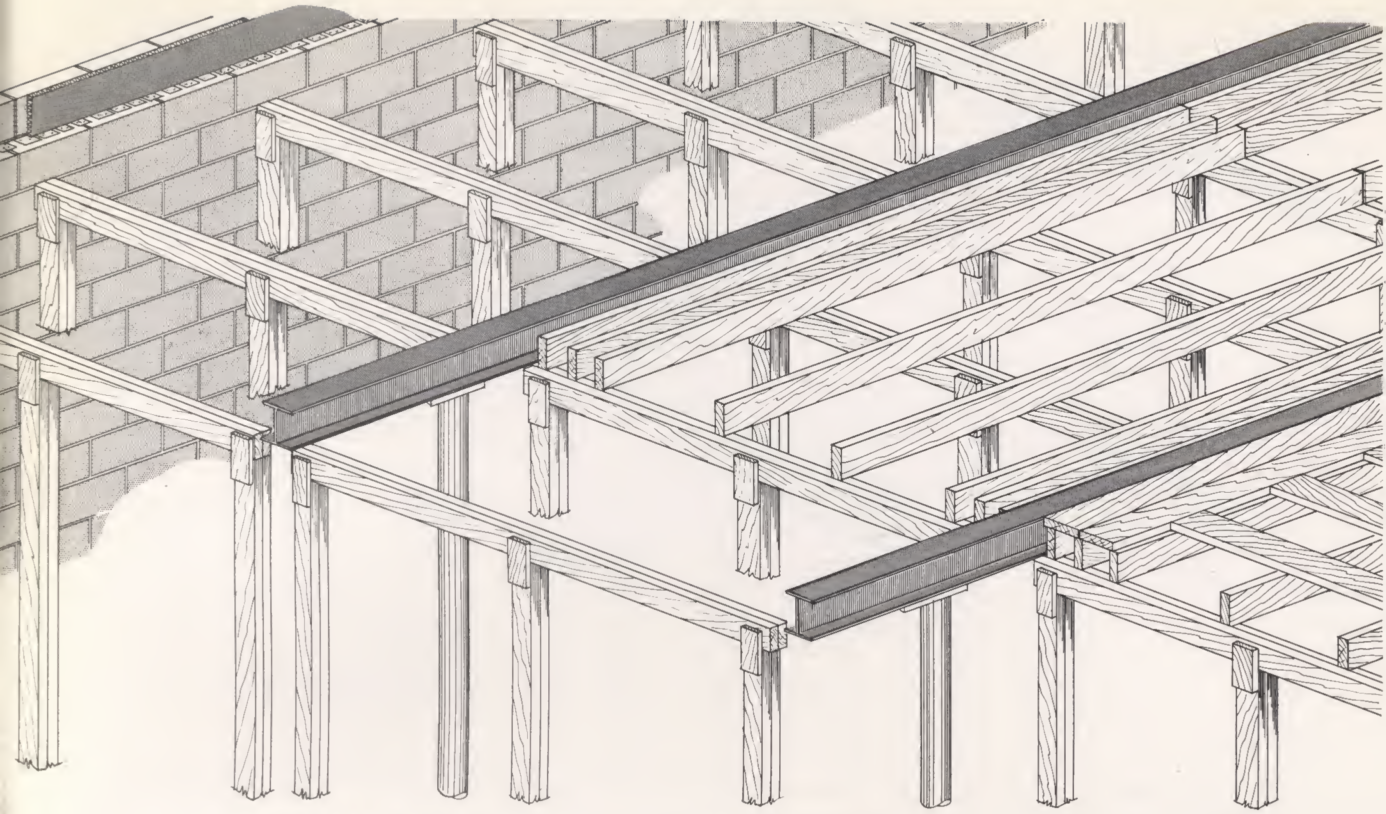
The floor may be formed and the concrete cast a section at a time in order to reuse formwork. However, all three spans should be formed and placed for the desired length of section.



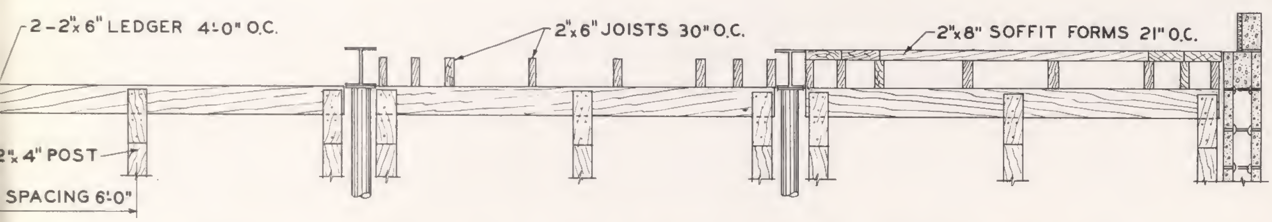
FORMING 4" BLOCK 2½" TOPPING



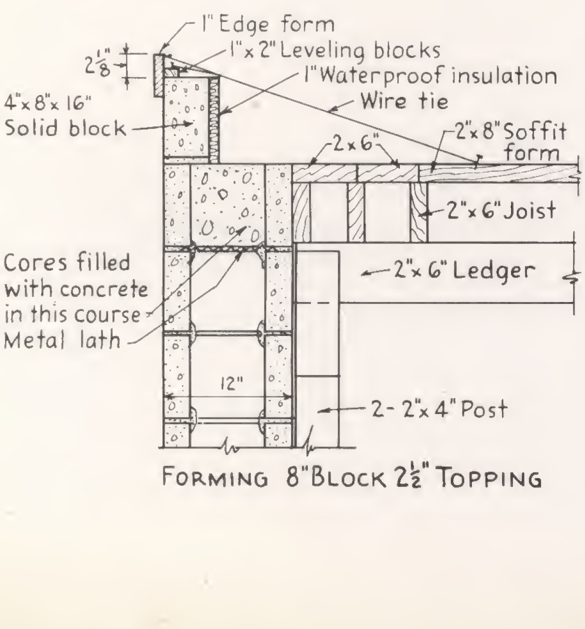
FORMING 6" BLOCK 2½" TOPPING



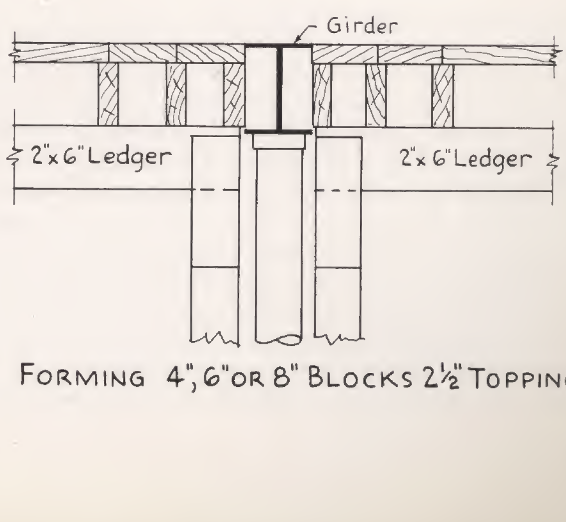
FORMING FOR BLOCK JOIST FLOORS



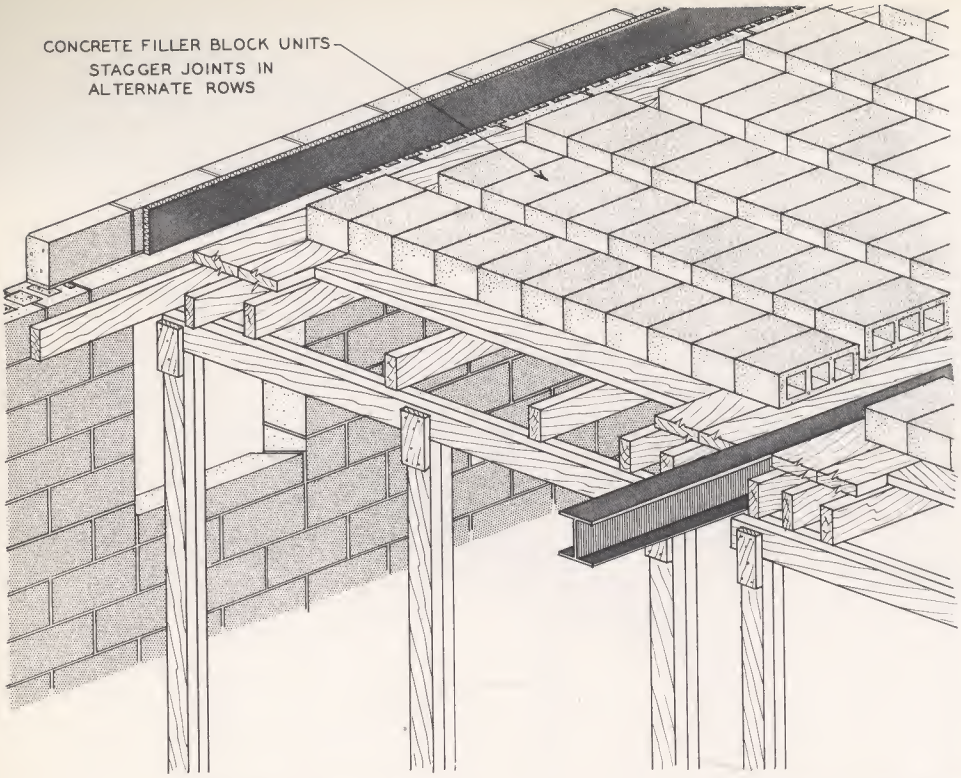
P 1-SET POSTS AND LEDGERS. STEP 2-SET WOOD JOISTS. STEP 3-PLACE SOFFIT FORMS.

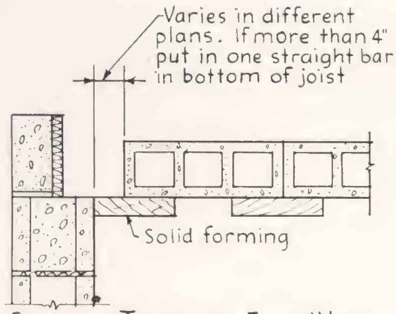


FORMING 8" BLOCK 2½" TOPPING

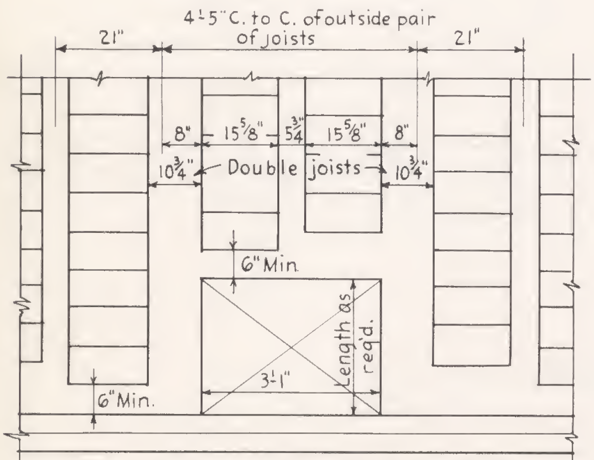


FORMING 4", 6" OR 8" BLOCKS 2½" TOPPING

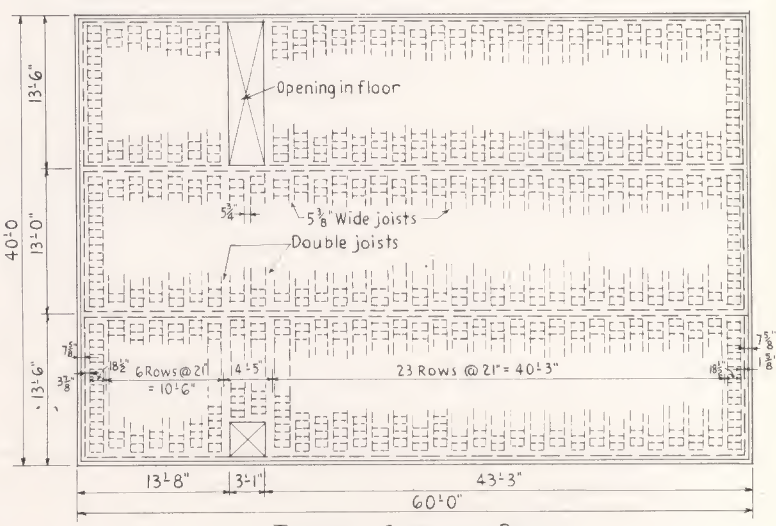




SECTION THROUGH END WALL



ENLARGED DETAIL AT FLOOR OPENING
FOR OPENING 2 BLOCK ROWS WIDE



TYPICAL SETTING PLAN
BLOCK JOIST FLOOR

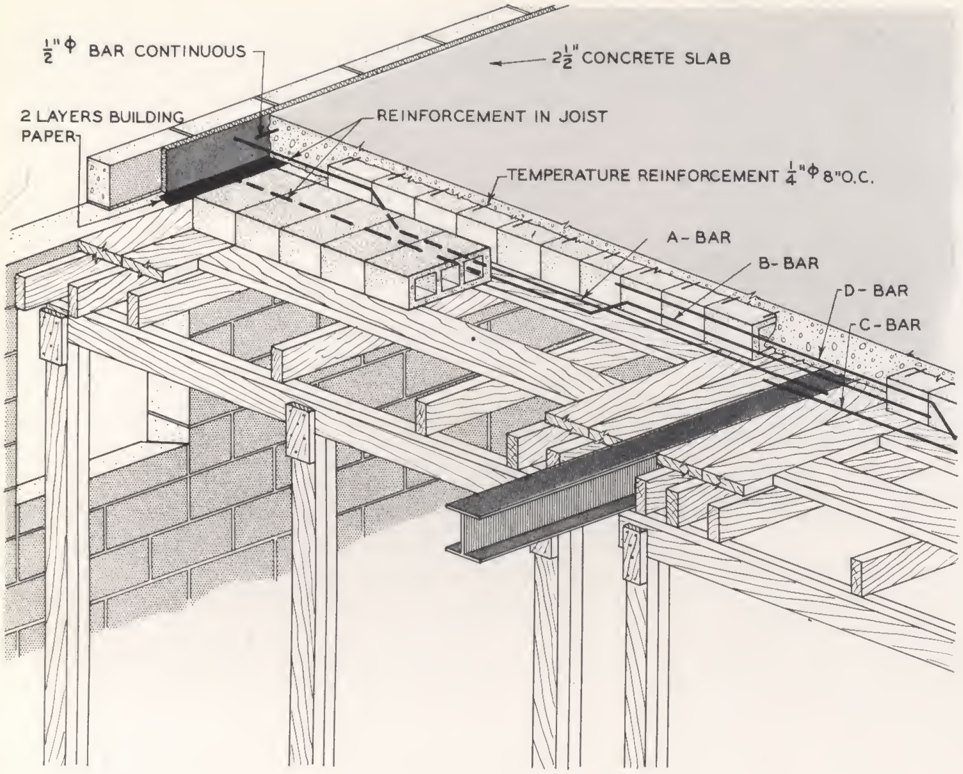
Setting Block

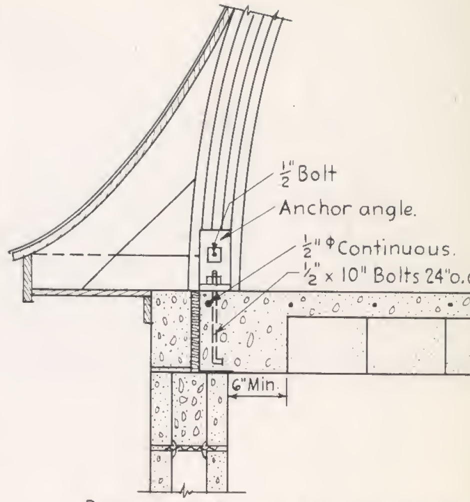
After erection of the formwork, the concrete filler block are placed in rows with a 5⅜-in. space between rows for the cast-in-place joists. The joints between block should be staggered in alternate rows by using a half-width block to start alternate rows, or the half block may be omitted. No block should be placed nearer the face of the support than 6 in.

The 5⅜-in. wide joists must be lined up in one span with those of the other spans. To accomplish this, it is advisable to draw a block setting plan similar to the one above. Openings in the floor may be framed between block rows as shown, or the floor around openings may be constructed of cast-in-place concrete, which gives a greater possible variation in opening sizes. Double joists (10¾ in. wide) should be used on each side of the opening and a reinforced header joist should be used at the end of the opening. This construction follows closely the framing methods used with wood floors.

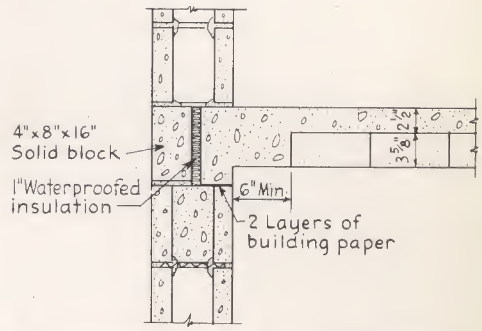
Fractional dimensions on the setting plan can be largely avoided by starting to dimension from the center line of the outermost joist which is used in framing the opening. Soffit forms are spaced at 21-in. centers from this point. The width of the end joists in the building, therefore, will vary on different plans. If the joist width is more than 4 in., one straight reinforcing bar should be placed in the bottom of the joist.

Two thicknesses of building paper should be laid on the bearing course of the concrete block walls before the concrete topping is placed. This will prevent the fresh concrete from bonding to the block wall and will allow slight movements in the floor and walls independent of each other.

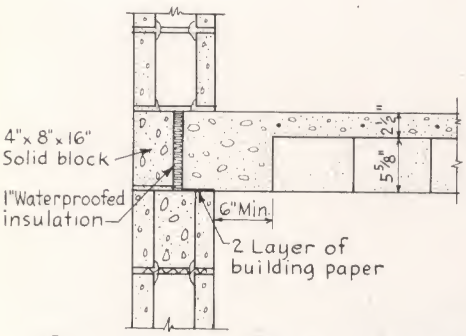




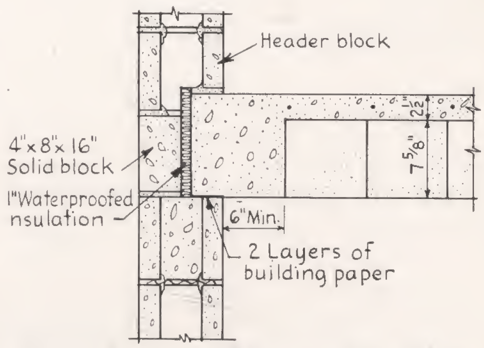
DETAIL OF RAFTER ANCHORAGE



CROSS SECTION THROUGH SIDE WALL
4" BLOCK 2½" TOPPING



CROSS SECTION THROUGH SIDE WALL
6" BLOCK 2½" TOPPING



CROSS SECTION THROUGH SIDE WALL
8" BLOCK 2½" TOPPING

Placing Steel, Concrete and Rafter Anchorages

Two steel bars are placed in each 5⅜-in. space between the rows of block. The sizes and shapes of these bars may be determined from Design Table B. In end spans the joist reinforcement consists of one *A* and one *B* bar. In interior spans the reinforcement consists of one *C* and one *D* bar. The *B* and *D* bars are bent upward at the fifth points of the clear span and extend into the adjacent span. The bars should be bent so that there will be ¾ in. of concrete covering them at the bottom of the joist and also ¾ in. of concrete over the top of them in their bent up position. See cross-section of floor in Design Table B, col. 1.

Shrinkage and temperature reinforcement should be provided in the concrete topping perpendicular to the joists. This steel consists of ¼-in. round bars at 8-in. centers. A continuous ½-in. round bar is placed along the outside edge of the floor.

High-quality concrete should be used for the joists and topping. For directions concerning the mixing, placing and curing of the concrete see page 23. If the roof is to be attached to the floor, bolts for the rafter anchorages may be set at 2-ft. centers, or a wood plate may be bolted on with bolts set at 4-ft. centers.

A concrete slab floor is rigid and stiff. It is economical for loads and span lengths found in farm buildings.

CONCRETE SLAB FLOORS

For the contractor who has had experience with reinforced concrete, the concrete slab is economical for the loads and span lengths encountered in farm buildings. Slab floors with one-way reinforcing are usually economical for intermediate to heavy loads on spans up to 12 or 14 ft. They are rigid and stiff, and stand vibrations or heavy, concentrated loads. For this reason, solid slabs are especially adaptable to floors for drive-in type buildings.

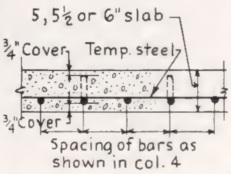
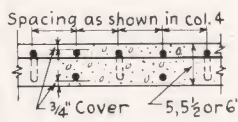
Other advantages of this type of floor are its minimum thickness and the resulting flat ceiling. If head room or total building height is limited, the thinner floor allows use of more vertical space. Flat ceilings have the advantage of being easily cleaned or painted.

The load-carrying abilities of 5-, 5½- and 6-in. thick concrete slabs having varying amounts of reinforcing steel are given in Design Table C. This table can be used for any number of spans greater than one but the spans should be of approximately equal length. The longest should not exceed the shortest by more than 20 per cent.

A qualified engineer can often reduce the amount of steel specified in Design Table C by resorting to a moment analysis for the particular case and by specifying a more intricate reinforcing bar schedule.

For a typical design prepared in such a manner, write for the booklet, *Concrete Hay Mow Floor*. Separate booklets are available for 32-, 34- and 36-ft. barn widths. These booklets also show cast-in-place concrete girders. Cast-in-place girders are often used with a slab floor. Where the construction crew has had experience in setting reinforcing steel, this type of construction may be quite economical since the girder may be designed as a tee beam.

Forming and concrete placing details for a slab floor are shown on pages 18 and 19.

Col. 1	Col. 2	Col. 3	Col. 4
Floor cross-section	Floor thickness (in.)	Dead load of floor (psf)	Reinforcing ... and ...
			A&B
 SECTION AT MIDSPAN	5	63	
	5½	69	
	6	75	
 SECTION NEAR SUPPORT	5	63	#3 @ 8″ #3 @ 6″ #4 @ 8″ #4 @ 6″ #5 @ 8″
	5½	69	#3 @ 8″ #3 @ 6″ #4 @ 8″ #4 @ 6″ #5 @ 8″ #5 @ 6″
	6	75	#6 @ 6″

Illustrative Design

PROBLEM: To design a concrete hayloft floor for a Michigan farmer. The barn will be built into a hillside and will have a drive-in type hayloft. A mechanical gutter cleaner and large comfort stalls will be used. No silo will be built.

STEP 1. Determine Spans. A barn width of 36 ft. will permit comfort stalls when a barn cleaner is used. A great number of span arrangements would be satisfactory in this case. Spans of 11-12-11 ft. are chosen. This satisfies the requirement on Design Table C that the spans should be approximately equal; the longest does not exceed the shortest by more than 20 per cent. (Clear spans will be less than these measurements by the length of bearing of the floor on the girder. Since this dimension is small and neglecting it is on the side of safety, the clear end or side spans will be considered as 11 ft. and the clear interior span as 12 ft.)

STEP 2. Determine Loads. Michigan will be found to be in Climatic Zone No. 1 on the map accompanying Table 4, page 3. The portion of the table which applies to Zone 1, when only hay is fed, shows that loads of 124 psf on end spans and 165 psf on the interior span will supply average hay and bedding needs. Since this is a drive-in type hayloft, heavier loads may be expected. If the driveway portion takes up 1/5 of the hayloft floor then 4/5 of the floor must carry the total hay load. In other words, loads will be increased by ¼:

1.25 x 124 = 155 psf on end spans
1.25 x 165 = 206 psf on interior spans

Dividing these loads by the applicable unit weights from Table 3 will give the approximate height of various materials that can safely be stored on the floor. In this case, baled hay could be stored about 11 ft. high on the end spans or chopped hay about 20 ft. high on the interior spans.

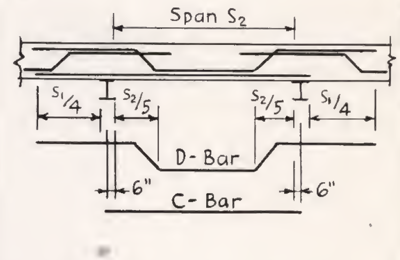
DESIGN TABLE C—Safe Superimposed Loads on Solid Cast-In-Place Concrete Floor

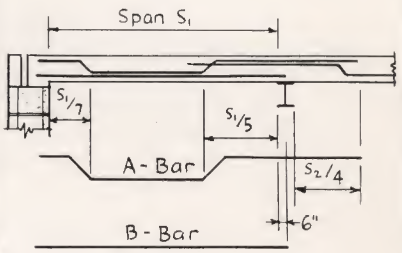
Col. 5

ar size / pacing C&D	Safe superimposed load (psf) on clear span of: (ft.) 8	9	10	11	12	13	14
INTERIOR SPANS $(+M = \frac{1}{16}wS_2^2;\ -M = \frac{1}{11}wS_2^2)$							
#3 @ 8″	118	80	53	33			
#3 @ 6″	168	119	85	59	39		
#4 @ 8″	*	177	132	98	72	52	36
#4 @ 6″	*	*	*	148	114	88	67
#5 @ 8″	*	*	*	178	139	110	86
#3 @ 8″	135	92	61	39			
#3 @ 6″	191	137	98	69	47	30	
#4 @ 8″	**	**	152	113	84	61	44
#4 @ 6″	**	**	**	171	132	103	79
#5 @ 8″	**	**	**	**	161	127	100
#5 @ 6″	**	**	**	**	**	185	150
#6 @ 6″	**	**	**	**	**	**	**
END SPANS $(+M = \frac{1}{11}wS_1^2;\ -M = \frac{1}{9}wS_1^2)$							
	85	54	32				
	126	86	58	37			
	186	134	96	69	47	31	
	*	*	146	109	82	60	43
	*	*	176	134	103	78	59
	98	63	38				
	144	99	67	44			
	**	154	111	80	56	38	
	**	**	168	127	96	71	52
	**	**	**	155	119	92	69
	**	**	**	**	175	139	110
	**	**	**	**	**	**	199

Col. 6

Shapes of bars





Bar nomenclature:
#3 = ⅜″φ #5 = ⅝″φ
#4 = ½″φ #6 = ¾″φ

Max. loads as limited by code or practice:
*188 psf
**200 psf

Allowable stresses:
Steel f_s = 20,000
Concrete f'_c = 2,500

Code:
ACI 318-51

The design load for the driveway section may be selected from Table 2. This table gives uniform loads equivalent to the concentrated loads produced by a truck having a total weight of 5 tons. The 11-ft. end spans should be designed for a uniform load of 173 psf and the 12-ft. interior spans should be designed for 166 psf. The amount of distribution steel to be provided perpendicular to the main reinforcement is also obtained from Table 2.

STEP 3. Determine Slab Depth and Reinforcing Required. The interior span being the longer and more heavily loaded will be designed first. For all portions except the driveway the load will be 206, the span will be 12 ft. Enter Design Table C at Column 5 with a span of 12 ft. Proceed down this column into the section headed *Interior Spans* and find a load of 206 lb. It will be found that the upper limit of the table is 200 psf signified by **. Reading horizontally from the first ** encountered yields the following information:

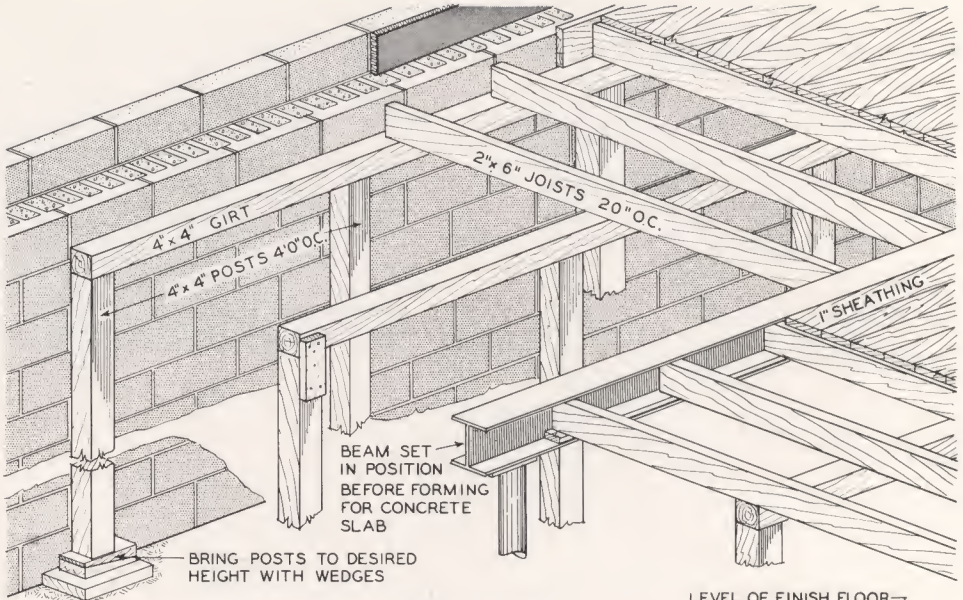
Column 2—5½-in. slab
Column 3—Slab dead load 69 psf
Column 4—*C* and *D* bars are each No. 5 bars and are spaced 6 in. apart
Column 6—The bars are bent to the shape shown

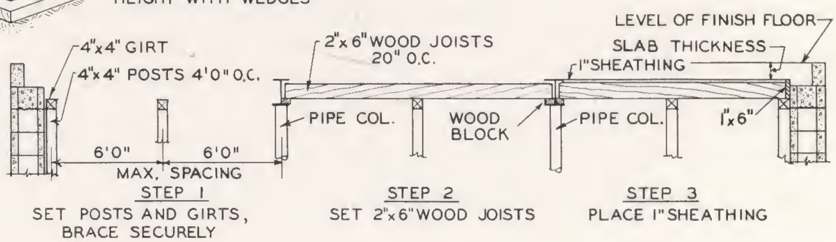
This design will safely carry a hay load of 200 psf which, considering the manner of increasing the load as discussed in Step 2, is probably satisfactory. Loads in excess of 200 psf are sufficiently heavy that an engineering analysis for the particular case is justified in preference to using tabular values.

With the exception of the driveway area, the design load on the 11-ft. end spans is 155 psf. Since a 5½-in. thick slab was required for the interior span, a 5½-in. slab will also be used for the end span. Repeating the procedure of design outlined above, but using the portion of the table headed *End Spans*, it will be found that *A* and *B* bars should be No. 5's spaced 8 in. apart.

In the driveway portion of the floor the design load on the 11-ft. end spans is 173. The floor thickness required to match that previously determined is 5½ in. From Design Table C it is found that *A* and *B* bars should be No. 5 bars spaced at 6-in. centers. Additional steel perpendicular to the *A* and *B* bars is required to distribute the concentrated wheel loads; the amount listed in Table 2 is 30 per cent. No. 5 bars may be used for this distribution steel. The spacing would be $\frac{6 \text{ in.}}{.30} = 20$ in. on center. These should be placed along the *B* bar, that is, near the top of the slab at the girder and near the bottom of the slab at all other points.

In the 12-ft. interior span, the reinforcement required to carry the 166 lb. design load is No. 5 *C* and *D* bars 6 in. apart. The amount of distribution steel required is 29 per cent. No. 5 bars may be used at $\frac{6 \text{ in.}}{.29} = 20$-in. centers. The distribution steel should be perpendicular to the *C* and *D* bars and placed near the top of the slab at the girders and near the bottom of the slab at midspan.





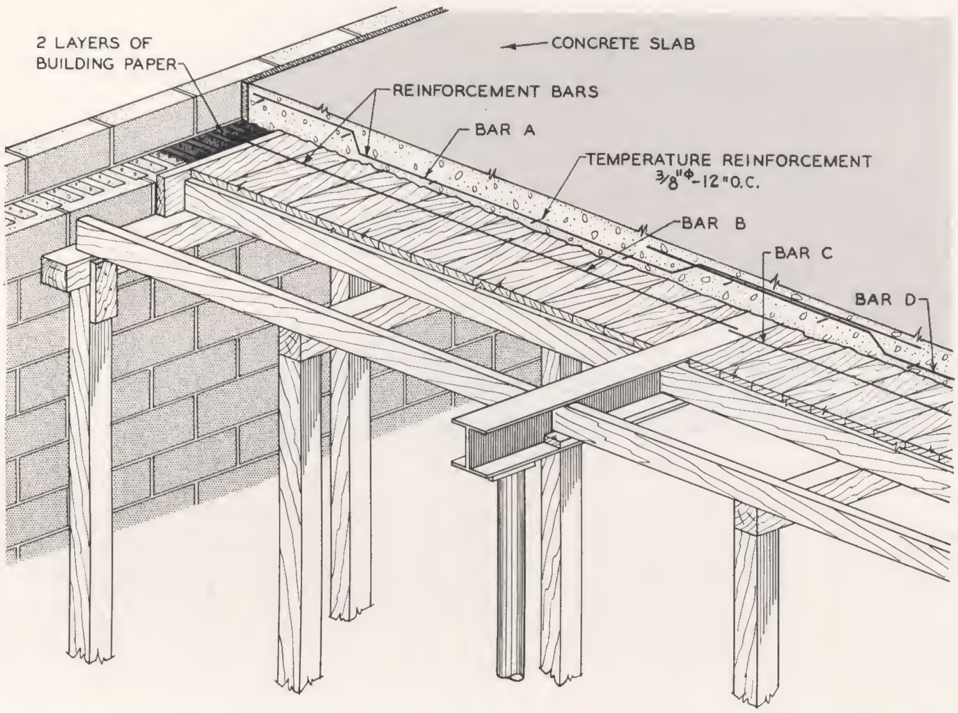
Forming

The concrete block walls of the barn are built to the height at which the floor will be placed. A facer course of 4x8x16-in. solid block are then placed around the perimeter of the barn to serve as a screed for the floor. This course of block should be uniformly level the whole way around. A 1- in. thick strip of waterproofed insulation is placed inside the course of facer units.

The steps in building the formwork for a solid concrete slab are shown in the drawings. Posts (4x4 in.) and girts (4x4 in.) are erected first. Girts are cleated to the posts with small pieces of 1- in. dimension lumber. The girts run parallel to the building length. Maximum distance between girts is about 6 ft. Posts should not be spaced more than 4 ft. on centers beneath the girts unless deeper girts are used. Posts must be securely braced in both directions.

Joists (2x6 in.) are set on top of the girts and perpendicular to them (parallel to the building width). If a structural steel girder is used the end of the joists may be supported on the lower flange of the girder; thus a row of posts and girts is unnecessary here. Joists are usually placed at 20- to 24-in. centers, depending on the type of sheathing used. A solid decking of 1-in. sheathing or plywood is placed on the joists. Nailing should be kept to a minimum to facilitate form stripping. Box nails or double-headed forming nails where they can be pulled are preferred. Toenailing should be avoided if possible.

Choice of forming materials should be carefully considered. Economy is achieved either by using forming materials several times or by using the lumber as forming only once, then utilizing it for other purposes elsewhere in the building. Experience has shown that, with reasonable care in nailing and stripping, No. 1 Douglas fir or Southern yellow pine sheathing may be used about three times for formwork. No. 2 sheathing can sometimes be reused a second time with some waste; No. 3 sheathing can seldom be reused as forms but is usable with waste elsewhere in the building. Plywood or other hardboard concrete forms offer considerably more reuse of forms, perhaps 8 to 10 times if excessive cutting or nailing is not required. Only the type of plywood made with waterproof glue is acceptable; interior plywood should not be used. Black iron forms may be used if available at a nominal cost. Galvanized iron forms may be used but usually must be left in place as they bond to the concrete.



Placing Steel, Concrete and Rafter Anchorages

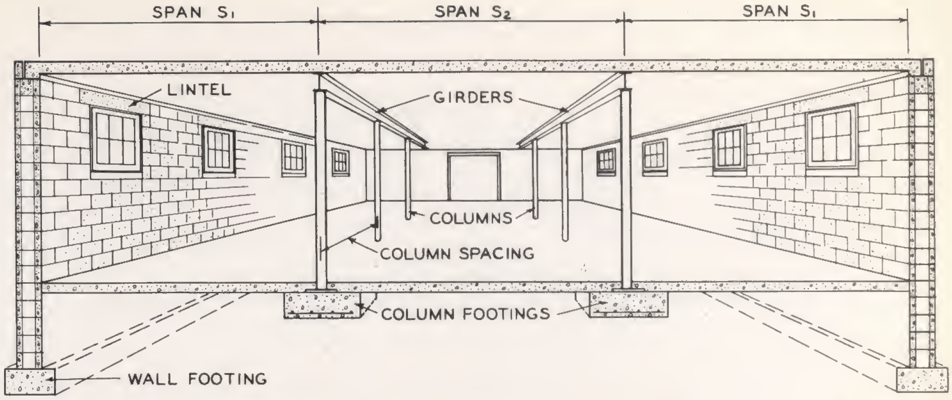
After the formwork has been erected, the accessories for holding the reinforcing bars at the desired height and spacing should be set. Bar chairs and slab spacers are usually available from the supplier of the reinforcing steel. It will generally prove less expensive to use standard type accessories than to depend on homemade substitutes.

The main steel (*A* & *B* bars in end spans, *C* & *D* bars in interior spans) is placed in the direction perpendicular to the girder. Temperature steel is required in the slab parallel to the girders. This temperature steel consists of ⅜-in. round (No. 3) bars placed 12 in. on center. A continuous ½-in. round (No. 4) bar is placed in the slab along the edge of the building.

In floors subjected to wheel loads, distribution steel perpendicular to the main steel is required as explained on page 17.

Bolts for wood plates may be set in the concrete floor at about 4-ft. spacings or the rafters can be attached directly to the floor by setting bolts at 2-ft. centers. Short sections of angles are later bolted to the floor and to the rafters.

High-quality concrete should be used in the floor slab. For information concerning the ingredients, mixing, placing and curing of the concrete see page 23.



OTHER STRUCTURAL PARTS

The engineer must specify sizes and spacings of several other structural parts in addition to the design of the concrete floor. These parts include columns, girders, lintels and footings. The graphs, drawings and explanations on the following pages will aid the designer in arriving at reasonable solutions to typical problems relating to these structural parts.

Column Size and Spacing

Round pipe columns are most commonly used for girder supports since they take up a minimum of floor area. Precast concrete or cast-in-place concrete columns may also be used. In dairy barns, the spacing of columns is usually dictated by the width of cow stalls; the columns are placed two or three stall widths apart. Usual stall widths for different size cows are shown in Table 6.

TABLE 6—Cow Stall Widths

Weight of cow (lb.)	Stall width
800	3 ft. 4 in.
1000	3 ft. 8 in.
1200	4 ft. 0 in.
1400	4 ft. 4 in.
1600	4 ft. 8 in.

The diameter of the column depends on the load it carries, its length, weight and kind of steel from which it was manufactured. Table 7 shows the allowable concentric loads on 4- and 5-in. columns made of standard weight pipe and from steel complying with ASTM Specification A7. Many manufacturers of barn equipment sell pipe columns and furnish their own safe load tables.

TABLE 7—Allowable Concentric Loads on Pipe Columns

Unbraced length (ft.)	Allowable load (lb.)	
	4-in. dia.	5-in. dia.
6	50,000	70,000
8	47,000	68,000
10	44,000	64,000

Column lengths are dependent on the height of ceiling required in the structure. A clear headroom of 6½ ft. is considered the minimum in an area where a person works. The usual height of dairy barn ceilings is 8 to 8½ ft. Ventilation, heating or operating requirements in different type structures cause modification of these heights to fit specific needs.

Column caps and bases are required to distribute the loads over larger areas where the column bears on concrete. These caps and bases are usually available with the columns. Since column bases are often exposed to severe corrosion conditions, they should be made of a corrosion-resistant material.

Girders

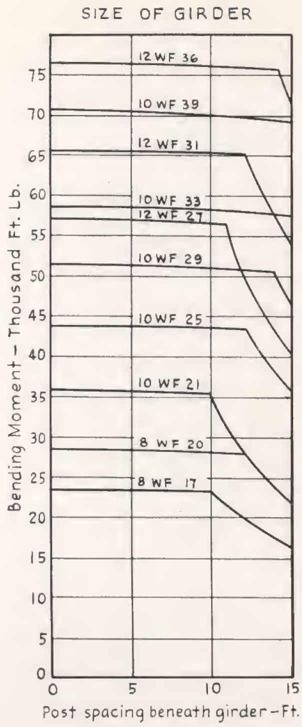
Girders which must carry heavy floor loads are usually made of cast-in-place concrete or of structural steel. Precast concrete members are often used as girders for more lightly loaded floors.

Structural steel girders are widely used in farm construction. Wide flange sections are most commonly used and are specified by depth and weight. Thus, 8 WF 20 means an 8-in. deep wide flange section weighing 20 plf.* Steel beams for specific loading conditions can usually be selected from tables or graphs with a minimum of calculations required. Fig. 3 is a portion of such a graph for laterally unsupported beams. The procedure for the use of the graph is explained beneath Fig. 3. This procedure assumes that the girder is spliced by bolting at each column point, the moment in the girder being $\frac{1}{8}\ wL^2$. For less frequent splice points in the girder the moment may be reduced in accordance with the degree of continuity provided.

The ends of the girder sometimes bear on the building wall or on pilasters built at the girder locations. If the girder rests on masonry, the cores of the block should be filled with concrete for the whole wall height beneath the girder end. Vertical reinforcing bars are also recommended. Metal bearing plates are often used to distribute the bearing load. For the more heavily loaded girders, such as in hayloft floors, girder ends may be supported on pipe columns. The pipe columns may be concealed in the block wall if desired.

*Pounds per lineal foot.

Fig. 3. Chart for selecting girder size.



PROCEDURE: (Fig. 3)

1. Determine total floor load on each span (psf)
   w_1 = Design load on S_1 + floor dead load of S_1 (from design table)
   w_2 = Design load on S_2 + floor dead load of S_2 (from design table)
2. Determine load on girder (plf)
   $w = \frac{1}{2}(w_1S_1 + w_2S_2)$ (S_1 and S_2 are in feet)
3. Determine girder moment (ft. kips)
   $M = \frac{wL^2}{8000}$ where L is the distance between columns in feet.
4. Select satisfactory girder from chart.
   Enter chart at bottom with column spacing (L). Project vertically upward on this line. Also enter chart at left with moment determined in (3). Project horizontally across on this line. Locate the intersection of these two lines. Any beam curve above this intersection will carry the moment. On close column spacings, shear in the girder should be checked.

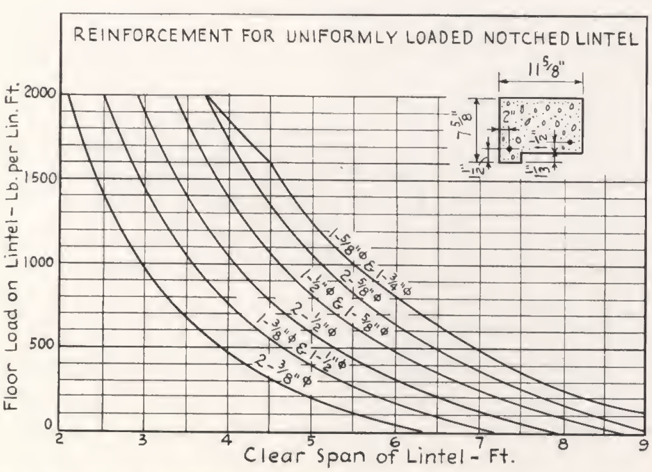


Fig. 4. Chart for selecting reinforcement for 12-in. wide notched lintel.

PROCEDURE: (Fig. 4 and 5)

1. Determine total floor load on end span (psf)
   w_1 = Design load on S_1 + floor dead load of S_1 (from design table)
2. Determine floor load on lintel (plf)
   $w = \frac{1}{2} S_1 w_1$ (S_1 is in feet)
3. Determine clear span of lintel in feet (L)
   L = opening width
4. Select lintel reinforcement.
   Enter chart at bottom with lintel span (L). Project vertically upward on this line. Also enter chart at left with floor load on lintel determined in (2). Project horizontally across on this line. Locate the intersection of these two lines. Any curve above this intersection will provide sufficient reinforcing for the lintel.
   For Wall Load Only: Enter chart at left with zero floor load. Move horizontally across to clear span of lintel required. Read reinforcing from next curve above.

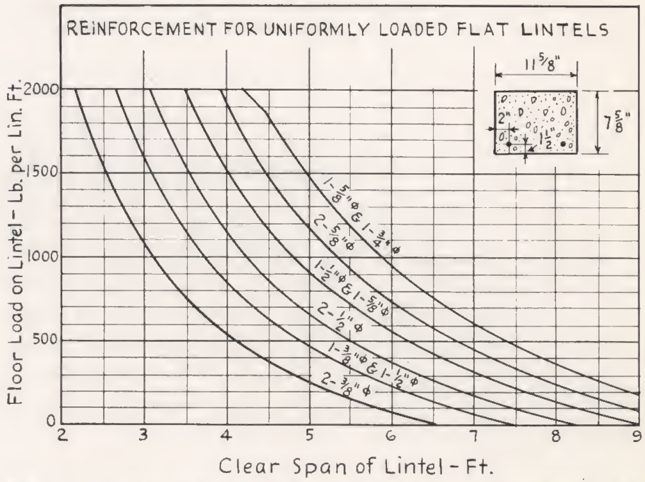


Fig. 5. Chart for selecting reinforcement for 12-in. wide flat lintel.

Lintels

Loads over the tops of windows and doors are carried by lintels. In concrete masonry buildings the most common type of lintel is reinforced concrete—either precast or cast in place. The reinforced concrete lintel is designed as a simple beam. It is made the same thickness as the masonry wall and the same height as one or more courses of block. Lintels bear one-half block length into the wall on each side of the window or door opening.

Two shapes of lintels are used in farm buildings—the flat bottom and the notched type. Flat bottom lintels are used with wood frame windows and doors. Metal windows use the notched type.

Some lintels carry only the weight of the wall above the opening. Such lintels usually occur in the end walls of buildings where the floor is not carried by the wall. Figs. 4 and 5 can be used to select the amount of reinforcing for 12-in. wide lintels carrying wall loads only. The procedure for making this selection is shown above.

Other lintels must be strong enough to carry floor and roof loads in addition to wall loads. This is usually true of the lintels in the side walls of the building. Figs. 4 and 5 give a method of selecting lintel size and reinforcement for a 12-in. block wall. This figure assumes that the lintel is uniformly

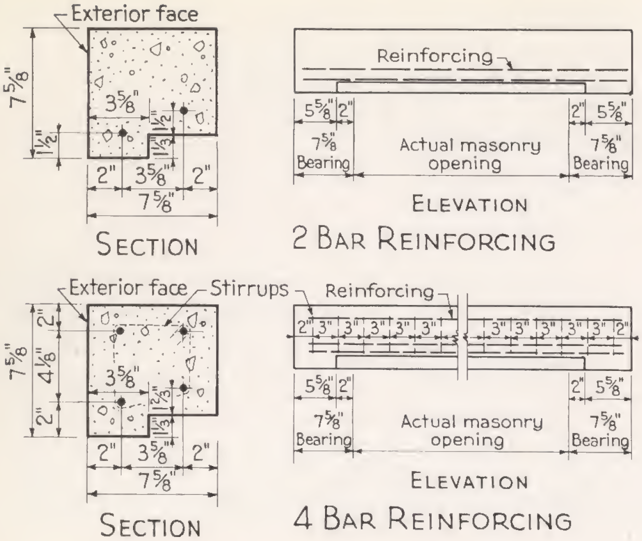


Fig. 6. 8-in. notched lintel.

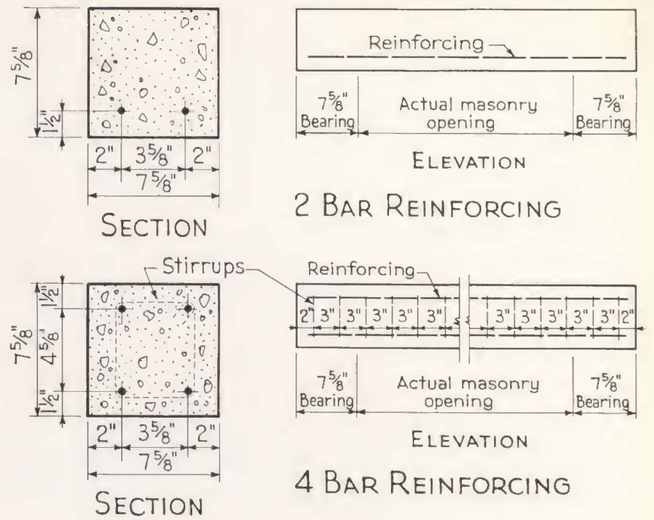


Fig. 7. 8-in. wide flat lintel.

loaded. For concentrated loadings such as those produced by precast joist floors, the lintel size should be calculated directly from the moment and shear in the beam. The user of the curves should be cautioned against any attempt to extend them beyond the conditions of load, span and reinforcement shown. If the design conditions do not fall into the range of the curves, then possible solutions are the use of continuous lintel bands, a lintel two courses deep, or structural steel sections for lintels.

On smaller, lightly loaded structures, 8-in. block walls are often used. Tables 8 and 9 show the lintels required for 8-in. walls. The reinforcement is positioned as shown in Figs. 6 and 7.

TABLE 8—Lintels With Wall Load Only

Size of lintel		Clear span of lintel ft.	Bottom reinforcement	
Height in.	Width in.		No. of bars	Size of bars
7⅝	7⅝	Up to 8	2	⅜-in. round deformed
7⅝	7⅝	8 to 9	2	½-in. round deformed
7⅝	7⅝	9 to 10	2	⅝-in. round deformed

Footings

Loads in farm buildings are transmitted to the soil through footings. Soils vary widely in the amount of load they will carry. Farm designs are usually based on a soil-bearing capacity of 2000 to 4000 psf. Table 10 gives the usual accepted load-carrying capacities of different types of soil.

Footings beneath walls are usually unreinforced and in common practice are made twice as wide as the wall is thick.

TABLE 10—Load Carrying Capacities of Soils

Type of soil	Capacity, tons per sq. ft.
Soft clay	1
Wet sand or firm clay	2
Fine, dry sand	3
Hard, dry clay or coarse sand	4
Gravel	6

Their thickness is usually the same as the wall thickness. Thus a footing beneath a 12-in. wall will usually be 24 in. wide and 12 in. thick. If extra-heavy loads are encountered, a check should be made to see that the allowable soil bearing is not exceeded.

The excavation for masonry wall footings should be deep enough so that the footings rest on firm, undisturbed earth beneath frost. This may be 4 ft. or more in cold areas. Depths should be at least 2 ft. in any case to prevent undermining.

Footings beneath the interior columns carry a great portion of the load in the building. These footings are usually made square and, if unreinforced, are half as thick as their side dimension. A 2-ft. square footing therefore is made 1 ft. thick. Unreinforced footings are ordinarily not made more than 3 ft. square. If larger footings are required for load, they are reinforced with steel bars. Fig. 8 shows the size of footings and the amount of reinforcement required for different loading conditions and different soil bearings. The procedures for chart use are explained beneath Fig. 8.

Column footings are placed on undisturbed soil and are usually constructed with their top surface flush with finished grade before the concrete floor is placed. The floor when placed rests on top of the footing.

TABLE 9—Lintels With Wall and Floor Loads

(Floor load assumed to be 85 psf with 20-ft. span)

Size of lintel		Clear span of lintel ft.	Reinforcement		Web reinforcement No. 6 gage wire stirrups. Spacings from end of lintel—both ends the same
Height in.	Width in.		Top	Bottom	
7⅝	7⅝	3	None	2—½-in. round	No stirrups required
7⅝	7⅝	4	None	2—¾-in. round	3 stirrups, Sp.: 2, 3, 3 in.
7⅝	7⅝	5	2—⅜-in. round	2—⅞-in. round	5 stirrups, Sp.: 2, 3, 3, 3, 3 in.
7⅝	7⅝	6	2—½-in. round	2—⅞-in. round	6 stirrups, Sp.: 2, 3, 3, 3, 3, 3 in.
7⅝	7⅝	7	2— 1-in. round	2— 1-in. round	9 stirrups, Sp.: 2, 2, 3, 3, 3, 3, 3, 3, 3 in.

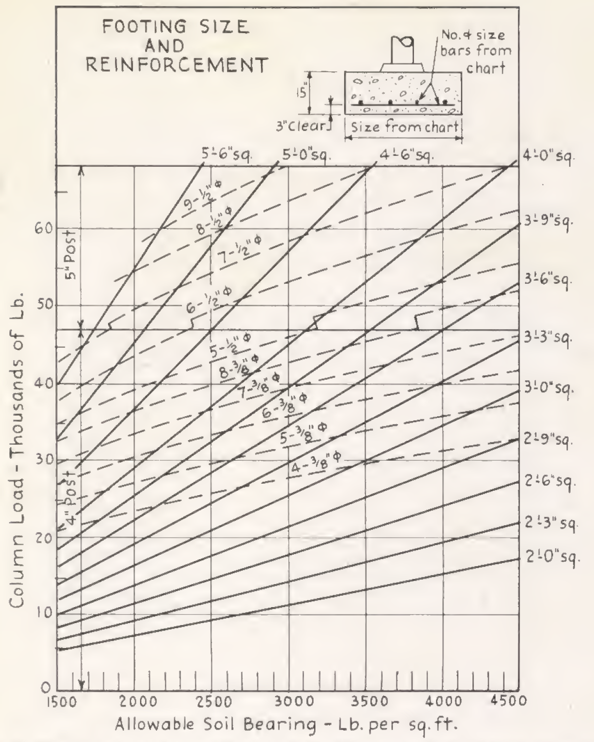


Fig. 8. Chart for selecting size and reinforcement of column footings

PROCEDURE: (Fig. 8)

1. Determine load on girder (w) (plf)
   This may be done by following Steps 1 and 2 in Fig. 7.
2. Determine load on column (R) (lb.)
   $R = 1.07\ wL$ where w is girder load in plf (from 1) and L is center to center spacing of columns.
3. Select size of column footings and reinforcing required.
   Enter chart at the bottom with allowable soil bearing. Project vertically upward on this line. Also enter chart at left with load determined in (2) above. Project horizontally across on this line. Locate the intersection of these two lines. The first solid straight line above this intersection gives the size footing required. The first broken curved line above this intersection gives the number of reinforcing bars to put in the footing in each direction.

Unreinforced Footings

Footings from 2 to 3 ft. square often are not reinforced. When unreinforced footings are used their thickness should be about half their side dimension.

Quality Concrete

Good quality concrete is essential in building any reinforced concrete floor. The design tables on the previous pages have been based on concrete having 28-day compressive strengths of 2500 or 3000 psi.* Concrete of this quality is not difficult to obtain on the farm. It can be made by selecting good ingredients, mixing them thoroughly in the correct proportion, and carefully placing and moist-curing the resultant mix.

Ingredients Portland cement should be free-flowing and void of lumps that cannot be easily broken up with the hand. If cement is stored prior to use it should be kept dry to prevent it from getting lumpy.

Aggregates to be used in concrete should be clean, hard and durable and should have a minimum of shale or other easily crushed particles. Aggregates are usually purchased and stored in two sizes. Fine aggregate, such as sand, has particles ranging in size from extremely fine up to ¼ in. Coarse aggregate, such as gravel or crushed stone, has particles from ¼ in. to a specified maximum size. For floors requiring 2- or 2½-in. toppings, this maximum size should not exceed ¾ in. Larger sized particles may be used in thicker floors.

Water used in making the concrete should be clean. A safe rule to follow is to use drinking water.

Proportioning and Mixing The following trial proportions of ingredients are recommended for the first batch of concrete:

For 2- to 2½-in. toppings	For 4½-in. or thicker floors
1 part portland cement	1 part portland cement
2 parts fine aggregate	2¼ parts fine aggregate
2¾ parts coarse aggregate (¾ in. max.)	3 parts coarse aggregate (1½ in. max.)

Not over 5 gal. of water for each sack of cement when the sand is wet (average).

If the first batch mixed according to these proportions does not produce the workability required, the amounts of coarse and fine aggregate may be varied in the next batch. The amount of water in proportion to the amount of cement should not be varied. Good concrete is mushy and workable; it is not thin and soupy. The materials should be mixed long enough to insure that all ingredients are thoroughly blended.

Placing, Finishing and Curing Concrete should be placed as near its final position as possible. It should be worked well into the forms and between reinforcing bars by spading or vibrating. The mushy mix can then be struck off to the desired level with a screed board. Final leveling is done with a wood-float. No more finishing need be done if a uniform, yet gritty and slipproof, surface is desired. Around stair openings a broomed finish on the concrete provides even greater slipproofing. The broomed finish is achieved by drawing a stiff bristle broom across the fresh concrete. Floors for grain or concentrate storage should be smooth to permit easy scooping. A smooth finish is obtained by trowelling. The steel trowel should be used sparingly after the concrete has become quite stiff and after the watery sheen has left the floated surface.

If concrete placing is stopped long enough for one section to set before fresh concrete is placed next to it, the following practices should be observed to insure good bond between the two sections. An edge form should be set so that the concrete will have a smooth vertical edge at the joint. When concreting is resumed, the vertical edge should be cleaned and thoroughly dampened. A cement-sand mortar should be slushed on the dampened edge, then the fresh concrete may be placed.

After the concrete has achieved its initial set, it should be kept moist for at least a week. This moist-curing is essential to develop the concrete strength and also to secure a dense, hard surface. The floor may be covered with straw or burlap and sprinkled at frequent intervals. Covering the fresh concrete with a waterproof paper or with a reliable curing compound also is satisfactory. If concreting is done in cold weather the concrete must be kept warm as well as wet.

Forms which support the concrete should not be removed for at least 3 to 5 days if the concrete has been kept continuously wet and warm. If less curing has been done, longer periods may be required before form removal. Design loads should not be placed on the floor for about a month after placing.

*Pounds per square inch.

A concrete roof on a single-story barn protects the animals in case fire breaks out in a nearby building.

Concrete floors or roofs on artificial insemination barns protect priceless breeding stock from destruction by fire.

Above. Good seed is valuable—seed houses with concrete floors, roofs and walls protect the seed from fire. *Below.* A concrete roof on this farm machine shed also serves as a smooth floor for the overhead grain bins. Bins can easily be emptied by gravity into a wagon, truck or grinder below.

OTHER FARM USES

Since farm buildings are grouped closely on the farmstead, firesafety becomes important in all types of buildings. Even structures which have no fire hazard within themselves, such as single-story animal shelters, may be exposed to a nearby fire. Concrete side walls and a concrete roof on such buildings are valuable aids in preventing the spread of fire.

Certain farm structures such as the farm shop, fuel storage houses, and grain or hay storages where heated air is used for crop conditioning present extraordinary fire hazards. Concrete structures help confine a fire in case it breaks out within these buildings.

Many commercial farm-related structures are commonly built with concrete floors or roofs because of the firesafety furnished. Hybrid seed corn plants, cotton storage warehouses, mill buildings, alfalfa dehydrating plants, hatcheries and artificial insemination barns are just a few of the many such uses.

Patented Floor Systems

There are several patented adaptations of the three basic types of floors shown on the previous pages, some of which have definite advantages for farm construction. Many of the patented systems require no forming or steel setting whatsoever. The manufacturer of each type of floor usually has available safe load tables for that floor system. Quite often he can also recommend builders who have had experience with that type floor*.

*For further information on patented floor systems see "Advances in Precast Floor Systems" by F. N. Menefee, *Journal of the American Concrete Institute,* October 1951, p. 113.

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A concrete roof on a single-story barn protects the animals in case fire breaks out in a nearby building.

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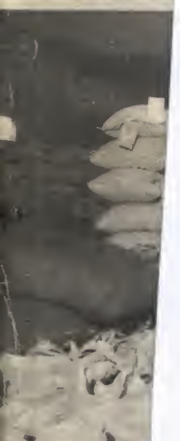

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